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ABSTRACT

This guide is for preservice and inservice early childhood educators and presents ideas for active learning in science and mathematics. The child-centered and active-learning experiences represent three categories of learning opportunities: (1) projects; (2) activity series; and (3) activity centers. The experiences emphasize creating meaningful learning experiences, promoting reflection and discussion, and connecting new events to prior experiences. The material is organized by chapter and includes three chapters on supporting learning, seven chapters providing examples of activity series, four chapters pertaining to activity centers, five chapters devoted to the project approach, and seven chapters that delve deeply into the issues and practices related to the integration of mathematics and science instruction across the curriculum. Each chapter contains specific classroom examples and proven strategies. (DDR)

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Creative Childhood Experiences in Mathematics and Science

by

Peter Rillero & Jeanette Allison

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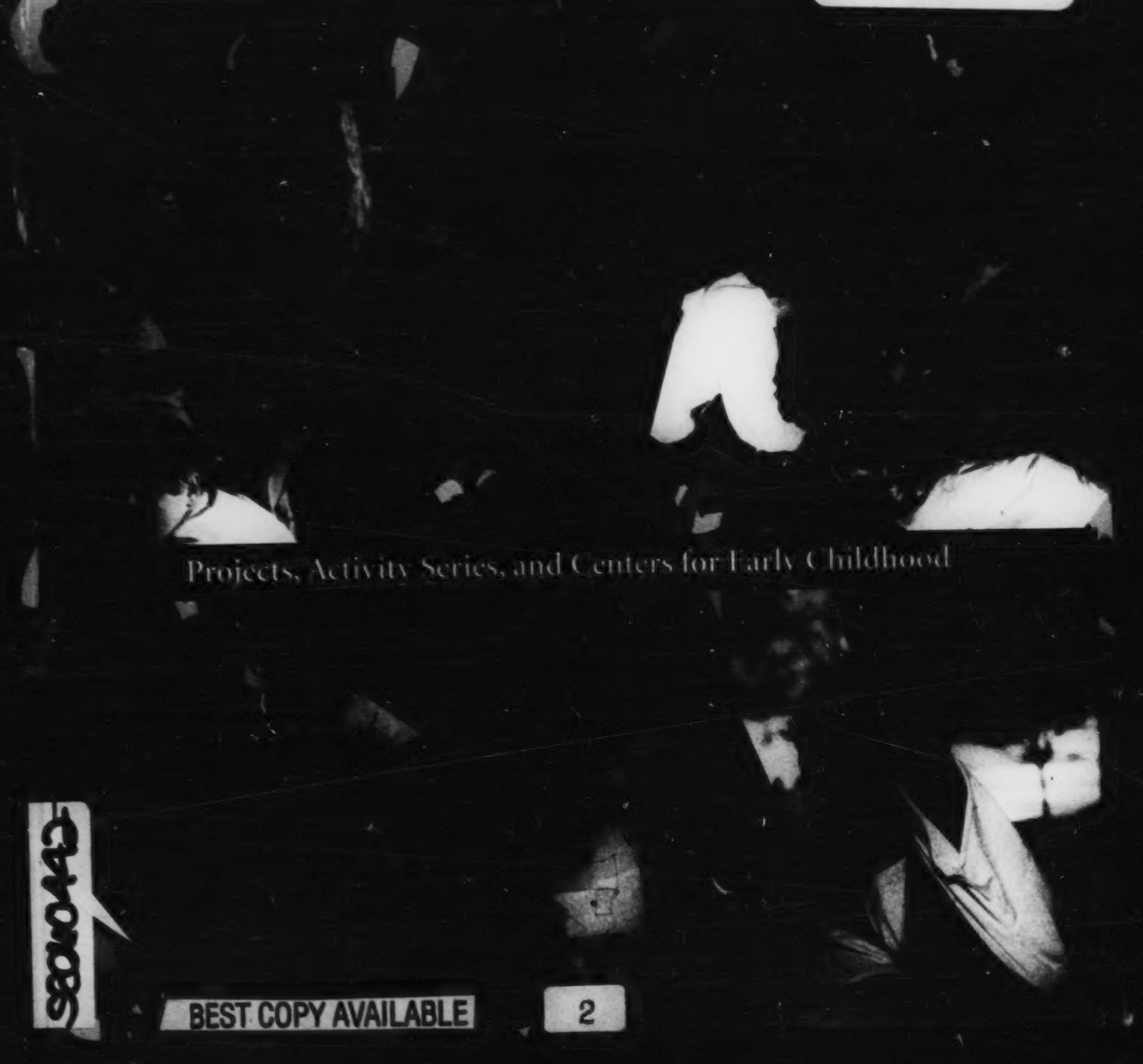

Projects, Activity Series, and Centers for Early Childhood

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Peter Rillero and Jeanette Allison

ERIC Clearinghouse for Science, Mathematics,
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Dedicated to our parents

In the early years of our lives
the events and experiences you shared
have made us who we are today.

Thanks for caring and sharing.

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Preface

> "Life is but a sequence of events becoming elements within a theme."
> Katya De Luisa, Foto-Collage Artist, Costa Rica

We are what we live and have lived. Life experiences make us who we are; the sequences of events become "elements within a theme." While there is little control over some episodes in life, we can nevertheless direct our growth by choosing to experience certain events, such as raising a family, traveling to a foreign land, caring for a sick person, or painting a landscape. What we experience and what we do are more than forces shaping our lives; they become us—more real and more important than our physical entities.

Watch an infant grow. Events in the life of a child are the life of the child. They observe, participate, and react to their experiences. Maturity brings the ability to reflect and discuss events making their potential impact even larger. From the moment of inception—when children receive their unique combination of genetic material—who they are, what they are, and perhaps even why they are—is a result of the events of their lives.

Effective education focuses on producing "event-full" learning. The emphasis is on (a) creating meaningful experiences, (b) promoting reflection and discussion, and (c) connecting new events to prior experiences. With these foci, learning occurs in an event-full and natural manner

We wrote this book for preservice and inservice early childhood educators. The book presents ideas for event-full learning in science and mathematics. The child-centered and active-learning experiences presented represent three categories of event-full learning opportunities: projects, activity series, and activity centers. While these categories overlap in some areas and may not be conceptually pure, we find them useful because they are familiar terms to many educators. Terms in education may have many meanings; for clarity we present our definitions.

Activity Series are sequences of dynamic events for promoting conceptual development. Effective activity series focus on a few key concepts. Events in the series are linked and occur over a period of time.

Activity Centers are autonomous areas in learning environments where children investigate aspects of their world. Centers use integrated and interactive activities.

Projects are in-depth investigations of topics that are of interest to children. Topics should have real world focus and application. They are long-term, usually two weeks or more in duration.

A clearer explanation for these approaches may be contained in a metaphor. If we view the world as a forest, in didactic approaches teachers tell the students about the forest and perhaps have them read about it. In activity series, centers, and projects children and teachers go directly into the forest to experience it. In an activity series, a class approaches the forest and children and teachers walk in on a path. The path brings them in contact with active learning experiences; some of these have been predetermined, others have been developed based on observing students and their needs in the forest. Most of these experiences require children to work in small groups or individually, but the class combines, discusses events, and continues to walk together.

In the activity centers approach, children walk into the forest. Some children may break away from the group and conduct learning activities. At times the entire class may form groups of various sizes to study different phenomena . The number of experiences depends upon the child. Some will experience more, others less, but they will come back having experienced the forest.

In the project method, students and teacher approach the forest and walk in. There is no predetermined trail. The group walks where they are most interested. On their journey they encounter many active learning situations. Children perform many different roles as they traverse their trail of discovery.

There are advantages to each approach for children and teachers. Optimally, a classroom will provide events in all these areas. In the organization of the book we present each of the three approaches in its own section. Section Two of the book focuses on Activity Series; Section Three on Activity Centers; and Section Four on Projects. Section One presents ideas on how to get started in "event-centered" learning, how to maintain it, and how to maximize it.

The events in this book were chosen because of their ability to promote science and mathematics learning. We chose these content areas because they are often neglected in early childhood education. But the events themselves do not fall into the rigid confines of an academic discipline; rather, they treat the child and the child's world as whole. The chapters selected for this book offer ideas as to how teachers can accomplish this. A central practice in treating the child as a whole is with curriculum integration. Section Five discusses and presents examples of how content and method can be integrated.

Constructivism and developmental theories are propelling thought and action towards more child-centered instruction. From these theoretical perspectives the authors have developed practical applications. At the core, is a focus on events in the life of a child. What do you remember about your childhood? Events of your childhood have formed your memories and influenced who you have become. Education that focuses on the child focuses on events; education that focuses on the world includes science and mathematics. We hope this book helps you create an event-full learning environment that enables children to better understand the world.

Peter Rillero

Section 1

Supporting Learning

Chapters in this section focus on how to effectively implement activity series and centers, and projects, from both theoretical and practical perspectives. Perhaps the most immediately useful information focuses on teaching strategies and techniques, but effective teachers also know *why* they do what they do. This is where the theoretical background comes in. Theory and research can inform what teachers do, providing them support in their quest to offer meaningful education to students.

Jeanette Allison begins Section 1 by addressing *topics.* Deciding which topic is most meaningful for students can be a challenging task. There are, however, steps teachers can take to make this process successful. Jeanette shares her experiences in selecting worthwhile topics for inquiry-oriented learning, such as with activity series and centers, and projects. Criteria for topic selection are provided, and substantive topics are suggested to help teachers get started. Topics that address science and mathematics standards are presented as well.

In the first half of her chapter, Julie Thomas describes inquiry as *how* students learn across projects, centers, and activity sequences. She provides suggestions for including inquiry in all content areas, integrating the curriculum. While inquiry focuses on the learner, curriculum integration focuses on the teacher and what happens in the classroom. Julie provides a model of curriculum integration to show different ways integration can occur. The model is useful when trying to understand differences across activity series and centers, and projects. The chapter also includes information on how to: (a) guide student inquiry and thinking; (b) combine mathematics, science, and other content areas; (c) make connections across ideas, facts, and approaches; (d) manage hands-on learning; (e) organize materials and resources; and (f) conduct assessment.

The second half of the Thomas chapter includes in-depth descriptions of two integrated curriculum programs: *Activities that Integrate Math and Science (AIMS),* and *Great Explorations in Math and Science (GEMS).* These two programs are examples of how inquiry can be placed at the center of learning.

Julie also offers suggestions based on a constructivist view of learning. She explains that curriculum integration, "has its roots in constructivism," and that constructivism explains why activity series and centers, and projects are meaningful to learners: they contribute to student knowledge bases through repeated exploratory opportunities. The constructivist view of learning also relates to other approaches presented in this book, though the approaches described here represent an array of learning theories that prioritize inquiry learning, and are not based on constructivism alone.

Sullenger and Holland devote their chapter to identifying and overcoming limitations to activity series and centers, and projects. They describe how to solve challenges of learning and teaching related to inquiry and curriculum integration, challenges such as students' prior experiences and capabilities, different teaching approaches, various program structures, and types of resources. Each challenge, or limitation is first explained, then followed by an example and useful sections called *Ideas to Try* and *For Starters.* They provide specific instances of limitations and suggested solutions. For example, when discussing "Language" as a potential barrier they describe how to help students who speak English as a second language. They suggest resources to help students understand the *meaning* behind language and ideas. They also suggest linking students with scientists and other people in the community.

Sullenger and Holland complement Thomas' discussion on constructivism in their presentation of "Instructional Approaches," a continuum of teaching/learning approaches, ranging from teacher-directed to learner-centered. The continuum helps clarify how teaching approaches compare in placing students at the forefront of their own learning.

This continuum demonstrates, in part, how the activity series and centers, and projects in this book differ, and yet complement one another. As is readily detected, authors throughout the book vary slightly in their interpretations of education that is "learner-centered," "inquiry-oriented," and "integrated." Despite the variations, the authors' main beliefs and understandings are consistent across approaches.

Chapter 1

Topics

Jeanette Allison

Choosing a topic is an important first step in developing valuable learning opportunities for children. The strength of a topic directly affects the success of learning plans. Topic choice can significantly affect what children actually accomplish and learn. In other words, a topic can "make or break" the best of plans in terms of children's long-term interest, motivation, and focus.

What is a relevant topic? Are all topics equally relevant for activity series, centers, or projects? Throughout this book, relevant topics are presented, and, likewise, topics that seem less relevant are identified. Keep in mind, though, that there is no "perfect" topic. Many topics are potential vehicles for learning. However, some topics are more *relevant* than others for children's educational and developmental needs.

Two General Characteristics of Relevant Topics

Over the years, many educators have addressed relevance in topic choice, and have identified the characteristics and benefits of strong topics, and their recommendations can be used to select relevant topics (Dearden, 1984; Hartman & Eckerty, 1995; Katz & Chard, 1989; Spodek, 1991). Relevant topics share at least two general characteristics: they are specific to children's lives, and yet they address common issues among children.

Specific to Children's Lives

How "good" a topic is depends on the local context, the people, things, demographics, terrains, and resources in children's lives. What is considered a "good" topic differs for children, because their experiences influence their topic preferences. For instance, children in Phoenix, Arizona would benefit more from the topic "Water Sources in the Desert" than would children living in Buffalo, New York. The importance of a topic also depends on children's curiosities which change daily. Therefore, it is not very realistic to pre-plan a lot of curriculum that is implemented the same way every year. Even though this practice is common, it exists mainly as a habit of convenience. Worthwhile learning experiences change with children and the local context; they usually are not based on a fixed curriculum with lesson plans that rarely change.

Common Issues Among Children

Some topics are relevant across contexts (e.g., places, events, circumstances, people), and can be studied by all children regardless of where they live, because all people share some common experiences. Consider the idea that "We all need shelter." Teachers worldwide could offer the topic "Shelter: What Kinds Are There?" which would be relevant to all children as long as it is tailored to their lives. Children without traditional homes could discuss methods they could use to secure shelter, such as living with another family or in alternative environments like shelters, group homes, or self-made structures.

There are also topics that interest children who do not have the full advantage of living in the immediate context. For example, children around the world could study topics related to the Olympics, even though the event is held in a particular city. Though most children cannot directly examine scenes of such major events, they can indirectly participate in nationally and locally recognized events.

Specific Characteristics of Relevant Topics

In addition to the general recommendations above, relevant topics also share specific characteristics. They:

- *Require children to invest themselves fully in the learning process.*
- *Involve many learning domains (e.g., intellectual, social, physical, and emotional).*
- *Involve many curriculum areas (e.g., math, science, social studies, literacy, the arts, etc.).*
- *Act as a compass, not a predetermined road map—general direction is indicated, but specific destinations are open to children's initiatives.*
- *Are based on real phenomena.*
- *Contribute to knowledge and skills that children can* use.
- *Shift in focus; one topic leads naturally to another (e.g., from "cafeteria" to "restaurant" and then to "grocery store").*
- *Are not "fool-proof;" they do not give teachers specific recipes for teaching. Instead, like the compass, relevant topics point in general directions, encourage risk-taking, and treat "mistakes" as learning opportunities.*

Strong Versus Weak Topics

Another factor to consider in selecting topics is the strength of each topic in advancing children's education and development. Again, almost any topic offers a potential context for learning, but not all topics are worthy of children's time. Some topics play a strong role in children's learning, while others play a weaker role. Some topics can be considered both strong and weak, and fall into a "gray area." For convenience, I will discuss topics that seem mostly strong or mostly weak, though I realize that a topic is only as strong as the teacher who implements it. The examples presented here are based largely on children's responses to topics.

Strong Topics

What makes topics strong? Strong topics *engage* children in investigation of their world. In doing so, their thinking is challenged *throughout* learning, from beginning to end. Strong topics originate from children's demonstrated interests. They might pay particular attention to an event or professional, or may actually state out loud their curiosities.

Topics that engage children often are based on long-term goals. Children literally become "absorbed" in the learning process because they have time to tailor learning to their curiosities, and individual strengths. Strong topics allow children to personalize the project as well, such as spontaneously having a birthday party in a 'house' they constructed. Consequently, children display a healthy intensity in their efforts. Strong topics focus on:

- *How things work (e.g., clocks, toasters, bicycles).*
- *Roles of people (e.g., the "cooker lady" in the cafeteria, electricians).*
- *How things are made (e.g., music videos, shoes).*

These topics provide children with useful information that spurs them on to know more.

Most of the time, engaging topics are not pre-selected by teachers, but are based on children's emerging ideas, experiences, or questions. If topics are pre-selected they still need to be greatly influenced by children's lives and input along the way.

Children can also offer many useful ideas for topic selection. Usually, children focus on topics that: (a) are complex (multidimensional), (b) relate to their lives in many ways,(c) engage them intellectually over time, and (d) change from year to year.

Teachers can heighten children's interest in topics by posing questions such as: How are houses built? What kinds of spiders are there? How are shoes made? What do (local animal) do to survive? Here, the teacher encourages children to state what they wonder about a topic. Some prompting by the teacher may help as well.

Weak Topics

In contrast to strong topics, *weak* topics may have initial appeal, but rarely stimulate children's intellects on a long-term basis (e.g., two weeks). Teachers often may find themselves "fanning the fire" in order to initiate a topic and keep children involved beyond the initial appeal.

Weak topics emphasize exposure to phenomena rather than engagement with them. Consequently, children have few opportunities to learn about their world "up close." They spend most of their time skimming the surface of learning, rather than really delving deeply into ideas.

What are examples of weak topics? These topics mainly entertain children, that is, they tickle children's minds but do not *deeply* stimulate them. Commonly, entertaining topics stem from things teachers prefer to know more about than do their children. The topics keep children busy, which can be a relief to a teacher, but children have little opportunity for intellectual involvement. This could be any topic *if* children do activity for activity's sake, rarely make intellectual connections across events and ideas, and merely dabble in the process.

Entertaining topics commonly are pre-selected by teachers or originate from traditions (e.g., holidays), curriculum handbooks, or workshops. Teachers often describe these topics as "fun," which they can be. Yet, what seem like "fun" topics to teachers may lack intellectual value. . The key is making substantive connections to children's interests; if children's interests are at the heart of topic choice, they will *enjoy* being involved with the topic for quite some time.

Some topics also can be described as "teacher preferred." Teachers can like certain topics, but should know that children may not equally like them. Teacher-preferred topics are often: (a) easy to develop, (b) familiar to the teacher, and (c) aligned with grade-level objectives for the district or program. These topics may be based on an idea or hobby that the *teacher* likes and wants to promote. If you select topics on the basis of your personal interest, be sure that children move beyond simple memorization of basic facts and information to delve into the deeper meanings of the concepts associated with the topics. It may be more appropriate to consult topics suggested by the National Research Council (for topics in science) and the National Council of Teachers of Mathematics.

Topics and National Standards

Consider science topics proposed in the *National Science Education Standards* (National Research Council, 1996), for instance. This is a useful place to start in choosing topics that align well with the science knowledge and skill standards for kindergarten through 4th grade. The standards emphasize: "Science as inquiry; abilities necessary to do scientific inquiry; and understanding scientific inquiry" (p. 105). Figure 1 presents topics related to content standards for kindergarten through 4th grade (p. 109; Please consult the publication for specific age and grade level applications).

Either/Or?

Is topic selection either child-based or teacher-based? Should topics never be predetermined? Not necessarily. Novice teachers and teachers implementing new approaches

- Unifying Concepts And Processes
  - Systems, order, and organization
  - Evidence, models, and explanation
  - Change, constancy, and measurement
  - Evolution and equilibrium
  - Form and function
- Science As Inquiry Standards
  - Abilities necessary to do scientific inquiry
  - Understanding about scientific inquiry
- Physical Science
  - Properties of objects and materials
  - Position and motion of objects
  - Light, heat, electricity, and magnetism
- Life Science
  - Characteristics of organisms
  - Life cycles of organisms
  - Organisms and environments
- Earth And Space Science
  - Properties of earth materials
  - Objects in the sky
  - Changes in earth and sky
- Science And Technology
  - Abilities of technological design
  - Understanding about science and technology
  - Abilities to distinguish between natural objects and objects made by human
- Science In Personal And Social Perspectives
  - Personal health
  - Characteristics and changes in populations
  - Types of resources
  - Changes in environments
  - Science and technology in local challenges
- History And Nature Of Science
  - Science as a human endeavor

Figure 1.1 *Topics Related to Content Standards*

may benefit from having "starter topics." A starter topic focuses on something familiar to the teacher. The key, however, is for the teacher to incorporate children's ideas as much as possible. With experience, the teacher bases learning more on what children want to investigate.

The strength of any topic is limited by the teacher's knowledge about the topic, and how well it is implemented. Consider a common topic, "Caterpillars," shown in Figure 1.2. This example contrasts less relevant activities and more relevant activities.

"Caterpillars" could be considered a weak topic if children just do activities for activities' sake. Children are busy, *but* make very few connections across activities, and there is little investigation. On the other hand, this topic could be deemed relevant when most, if not all, of child participation focuses on a larger, connected event and concept: That caterpillars' special

Topic: ***Caterpillar***

Less Relevant

- Group Time: *The Very Hungry Caterpillar*
- Caterpillar puppets in dramatic play
- Painting with green paint
- Drawing on green paper
- Manipulating green play dough
- Writing a class story titled, "If I Was a Caterpillar"

More Relevant

- Group Time: *The Very Hungry Caterpillar*
- Discussing characteristics, habits, and growth of caterpillars
- Comparing the book with discussions, and charting children's responses
- Visiting a professional gardener and talking about caterpillars' purposes
- Observing the life cycle of caterpillars
- Making connections across activities
- Developing class reports about real and pretend caterpillars, and their similarities and differences

Figure 1.2 *Possible Topic Activities*

roles in our environment can be observed. Each activity informs another activity that, in turn, informs another activity (Allison, in press).

More Topics to Seek

Other topics that potentially lead to quality learning opportunities are suggested by Borgia (1996). She also addresses topics to avoid. Like others, she asserts that topics must ensure that children investigate their real world, and she recommends that teachers *seek* topics related to:

- *Nature: trees, landscaping, parks, nature preserves, gardens, insects, animals, flowers, fruit, and vegetables.*
- *Water: ponds, rivers, bathing, water treatment, water towers, and similar topics.*
- *Community resources: retail stores, post offices, libraries, and similar topics.*
- *Vehicles: school buses, cars, trucks, tractors, trains, bicycles, and similar topics.*
- *Buildings: schools, cafeterias, windows, construction sites, and similar topics.*
- *Objects and materials: balls, baskets, boxes, clocks, hats, shoes, and similar topics.*

She also recommends that teachers not start with topics related to:

- *Things that are not real: fantasy television or movie characters, stuffed animals, or amusement attractions.*
- *The past: dinosaurs, historical events or people.*
- *Places or objects not in their surroundings: bottom of the ocean, the rainforest, etc. (p. 25).*

Of course, exactly which topics teachers need to seek and to avoid, and what children can learn with topics, depends ultimately on the immediate environment, resources, circumstances, and quality of teaching.

Additional Criteria for Choosing Topics

As stated earlier, many people have offered suggestions for topic selection. In addition to their suggestions, I offer six questions, or criteria, that can be useful in choosing topics (see also Hartman & Allison, 1996).

1. Does the topic focus on *concepts*? The topic helps children think about deeper-meaning ideas, messages, and themes.
2. Is the topic *generative*? The topic lends itself to ongoing investigation—one event, idea, and resource leads to another. There are connections across topics.
3. Is the topic *complex*? The topic has potential for depth of learning across multiple events and resources.
4. Does the topic make *use* of what children learn? There is a purpose to what children do, and they understand it and apply it to their lives.
5. Does the topic make learning an *accessible* event? Children have immediate and direct access to phenomena that they investigate. These phenomena are real, for the most part.
6. Is the topic *locally relevant?* What children do and learn is worth their time, and it informs them about their lives now. They focus on contributing to their surroundings.

It is desirable for topics to address all six questions, although combinations of the questions likely result in relevant topic selection (e.g., questions 1, 4, 5, and 6 mean that topics help children think about underlying ideas. Topics provide useful information for their lives in and out of school; they allow children to directly experience phenomena, and they relate to something familiar in the surroundings).

Summary

We just considered how strong and weak topics affect learning. We considered topics that are recommended, and some that are of questionable value. Some topics serve to entertain children, while others are meant to engage children intellectually. Some topics satisfy teacher concerns and objectives, while others originate from children's preferences.

After contrasting strong and weak topics above, it may seem obvious that one should think seriously about topic choice. Often, though, little critical attention is given to choosing topics. Instead, more attention is paid to determining the individual tasks in which children participate, and the immediate skills that children can show as "evidence" of learning.

The goal of relevant topic selection is to help children increase the depth of their thinking as they develop skills, knowledge, and attitudes about learning. When thinking about topic choice, keep in mind that some topics have more potential for success with children than others. Usually, topics that are naturally interesting to children will be successful overall. Topics that require more teacher invention may be less successful with children in the long run, due to children's lack of ownership and personal touches.

Seek topics that are naturally interesting to children and avoid spending energy initiating or maintaining children's interest in topics that do not naturally engage them. A strong topic offers children opportunities to examine phenomena directly and repeatedly. Such a topic also is based on children's pressing questions, evolving wonderments, and concepts *they* want to know about

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Chapter 2

Making Learning Meaningful

Julie Thomas

This chapter presents a rationale for integrated curricula, explains how to develop integrated curricula, and introduces guidelines for integrated teaching. A review of two integrated curriculum programs, *Activities that Integrate Math and Science (AIMS)* and *Great Explorations in Math and Science (GEMS),* offers examples of meaningful integration across content areas. In addition, there is a section on managing and assessing integrated curricula across content areas and approaches such as projects and activities.

Theoretical Framework of Curriculum Integration

Currently, national science and mathematics education reform initiatives call for an increase in the integration of science, mathematics, and other content areas. Documents such as *Science for All Americans* (American Association for the Advancement of Science, 1989) and *Everybody Counts: A Report to the Nation on the Future of Mathematics Education* (National Research Council, 1989) stress the interrelatedness of mathematics and science and the natural implication for curriculum development and instruction.

The integration of mathematics and science education is not new (Dubins, 1957; Kinney, 1930). The Central Association of Science and Mathematics teachers was organized around the turn of the century to bring a closer correlation between the two content areas. Now, again, science and mathematics professional organizations are promoting the integration of the two content areas. A decline in student achievement in mathematics and science has raised a concern for national strength in these areas.

In response to concerns, the National Council of Teachers of Mathematics (NCTM) (1989), the National Science Teachers Association (NSTA, 1983), and the American Association for the Advancement of Science(AAAS, 1989) issued challenges for reform in science, mathematics, and technology to enable children to solve real-world problems. The AAAS *Project 2061* (1992) calls for less curriculum content and more depth—encouraging teachers to find more connections across the content areas to support child inquiry. The NCTM (1989) has set curriculum standards which promote mathematics as a way of thinking—the language of problem solving. Teachers are encouraged to integrate this new mathematics instruction with other areas of the curriculum. Isaacs and Kelso (1996) suggest "this brand of science is naturally integrated with mathematics" (p. 340).

The integration of mathematics and science instruction makes intuitive sense, though few empirical attempts have been made to test this assumption. According to McBride and Silverman (1991), "While the results of empirical studies investigating the efficacy of integrating science and mathematics instruction are limited, they do indicate and support our intuitive beliefs about integration" (p. 287). More empirical research is needed regarding student motivation, understanding, and achievement as they relate to integration of mathematics and science.

Open-ended, Inquiry Learning

Integrated teaching changes the way teachers think about learning. It challenges teachers to take a different route in their lesson development. Jacobs (1989) suggests teachers put aside their content area orientation to consider general themes of interest to children. Teachers then select "organizing centers" which are neutral in character and do not depend on any one content area for their essential force, but include experiences or events that are universal to each student's background. Organizing centers around such concepts as Relationships, Exploration, Interconnections, or Change can then enable teachers to determine appropriate content and experiences. Teachers may begin with student questions or think of questions which will *grab* student interest. Next, learning materials can be selected that help children discover alternative solutions (and generate their own questions) while they are doing both mathematics and science.

This integrated planning process is the unfolding of a comprehensive framework for inquiry. It proves to be engaging because, textbooks become resources, separate content area times become larger time frames, and children become partner-teachers. Robert Tinker (in Berlin, 1994) argues that integrated teaching, by definition, is project oriented (see Project Approach Section of this book). He suggests that instead of teachers "teaching students," teachers "empower students to undertake original investigations to do math and science" (p. 35). With the end product determined and defined by the child, integrated mathematics and science teaching maximizes the opportunity for open-ended, inquiry learning.

Fogarty (1992) suggested that there are multiple models for curriculum design that follow along a continuum. These ten models indicate the variety of ways in which a teacher might plan curriculum connections that range from separate lessons to seamless connections. Curriculum can be fragmented, connected, nested, sequenced, shared, webbed, threaded, blended, immersed, or networked as is illustrated in Figure 2.1.

Figure 2.1 is reminiscent of Bloom's (1956) *Hierarchy of Thinking and Learning* ranging from the levels of knowledge and comprehension to higher levels of analysis, synthesis, and evaluation. Integration plans can be as simple as relating ideas across content areas and connecting overlapping concepts or as complex as threading skills through various content areas. Fogarty (1992) identifies integration terminology and clarifies the fine lines of meaning—from simple connections to real-world immersion. It is likely that traditional-oriented teachers will move toward the integrated-curriculum part of this continuum as they develop strategies with this approach. In moving towards integration, teachers can use the major markers on the continuum as guides for curriculum development.

Constructivist Theory

The philosophy of integrated curriculum has its roots in constructivism. Yager (1991) suggests that if understanding, synthesis, application, and the ability to use information in new situations is our goal in education, then a behaviorist approach, commonly associated with traditional teaching, is not successful. The constructivist paradigm posits that meaningful learning is constructed by learners as a result of sensory experiences with the world. Learners respond to sensory experiences by building or constructing schemas or cognitive structures in their minds which constitute the meaning and understanding of their world. "Individuals attempt to make sense of whatever situation or phenomenon they encounter, and a consequence of this sense making process is the establishment of structures in the mind" (Saunders, 1992, p. 136).

In order to develop these cognitive structures, children need maximal use of hands-on investigative laboratory activities which provide learners with a high degree of active cognitive involvement. A necessary condition for cognitive restructuring is an opportunity for repeated exploratory, inquiry-oriented behaviors with an event or phenomena. Then, learners can keep schema relatively unchanged, or revise schema to adjust to new data, measurements, or observations.

Curriculum Models

Model	What it Means	How it Works
Fragmented	traditional, separate and distinct content areas are fragmented by subject area	occasional, intentional relation of topics within distinct time slots for each area
Connected	attention to deliberate relationships within each content area	concept connections are identified (thermometers measure temperature and scientists collect temperature data)
Nested	multiple skills are targeted within a subject area (i.e. social skills, thinking skills, content skills, etc.)	a unit on cycles targets consensus seeking (social skill), sequencing (thinking skill), and water as a limited resource (content skill)
Sequenced	topics or units of study are sequenced to coincide with each other but remain separate subjects	children read *Jim and the Beanstalk* in language arts and study proportional measurement in mathematics
Shared	overlapping concepts become organizing elements for two content areas (or two teachers)	data collection (science) and charting and graphing (mathematics) are introduced together (may be team taught)
Webbed	a topical or conceptual theme connects curriculum areas	a topical theme (water) or conceptual theme (wonder) webs to content areas
Threaded	thinking skills, social skills, technology, and study skills are threaded through various content areas	prediction is targeted across content areas—predict next event in reading, predict next number in a pattern sequence in mathematics, and forecast current events
Blended	cross disciplinary approach blending four major content areas by finding overlapping skills, concepts, and attitudes in all four	observing spider silk, counting legs, and creating original spiders
Immersed	an immersed learner makes constant connections in the world of experience to a particular topic of interest	a highly motivated child, interested in insects, collects them, reads about them, writes about them, and draws them
Networked	learner filters learning through the expert's eyes making internal connections leading to external networks of experts in connected fields	a child interested in dinosaurs visits a museum curator "behind the scenes" (possibly meeting or interviewing related scientists such as geologists, anthropologists, or archeologists)

Figure 2.1 *Curriculum Integration Continuum (Adapted from Fogarty, 1992)*

Correlating Science and Mathematics with the Natural, Physical World

Science and mathematics are closely related systems of thought and are naturally correlated in the physical world. Science can provide children with concrete examples of abstract mathematical ideas that can improve the learning of mathematics concepts. Children learn best when they discover through their own concrete experiences (Berlin, 1989, 1990). Mathematics can enable children to achieve a deeper understanding of science concepts by providing ways to quantify and explain science relationships. Science activities illustrating mathematics concepts can provide relevance and motivation for learning mathematics.

According to a constructivist learning model, the natural world is necessarily integrated (Saunders, 1992). An integrated science and mathematics curriculum would support investigations as children accommodate their learning. During inquiry, children modify their cognitive structures, or schemas, as their knowledge base grows. In this curriculum, children might measure the mass of objects (mathematics) while they make observations about which objects float and which ones sink (science). Mathematics will help children understand the concepts of density and buoyancy. These understandings cause children to develop the cognitive structures necessary for meaningful learning to occur.

Based on teacher evaluations and classroom field tests of integrated curriculum, the *AIMS* Foundation (1996) reported that: (a) mathematics becomes more meaningful and better understood when applied to real-world situations; (b) science understanding is increased substantially through mathematics and science integration; (c) motivation increases when children are involved in real-world, hands-on investigations; and (d) student attitudes toward mathematics and science improve when children participate in successful, hands-on investigations.

In order for the United States to become a nation of thinkers and problem-solvers, teachers must move toward *why* rather than *how to* as the goal in mathematics—and education in general (National Research Council, 1989; NCTM, 1989).

> Teaching for understanding means children don't just memorize information but actively seek it, building relationships among data. It means that teachers are facilitators, not just preachers of facts. It means moving away from simply absorbing facts, to constructing knowledge. (McKinney, 1993, p. 7)

Integrating Curriculum in the Primary Classroom

Integrated teaching begins with an understanding of the meaning of integration. Confident, integrated teaching also involves an understanding of: (a) connecting content and topics, (b) managing schedules, (c) organizing learning materials, and (d) managing assessment.

Connecting Content and Topics

Some topics, content, and concepts will necessarily be determined by the school curriculum. Though the sequence and connections may change, the required curriculum can remain intact though focused on major unifying themes—the big picture. *Project 2061* (1989) recommends that children not be expected to learn detailed information, specialized vocabulary, and disparate facts. Consider the thematic webbing process in which a central theme or idea begins the planning process and brainstormed ideas and connections branch off from there.

Traditional content area categories can be softened while connections are emphasized. Think about overarching concepts that recur in all areas of science and mathematics. Possible concepts (themes, ideas, issues) include systems and interactions, patterns of change, stability, evolution, scale, energy, matter, structure, models and simulations (Great Explorations in Math and Science, 1991).

Consider also a year-long theme as a meaningful structure to connect learning. Greene (1991) wrote about a first grade teacher housed in a portable building while the new school was being built. Her year-long theme "Bit by Bit—Building it Together" involved her children in learning while observing. Children developed scale drawings of their bedrooms, produced blueprints of their classroom, and created buildings with blocks, legos, and tinkertoys while they read *The Three Little Pigs*. They studied rocks and soil (during excavation), sound (while the soundproofing was being installed), and plants (during landscaping). She suggested, "Clearly they learned that science is all around them—a part of their everyday lives—and will view their completed school with a special perspective" (p. 42). They will understand that science is part of many skills we use naturally each day, such as observation.

Managing Schedules and Content Area Times

Typically, science applications are not generally considered during the presentation of a standard mathematics lesson. More planning time and more instructional time is required to teach mathematics concepts through science activities. As mentioned previously, expect adjustments in the schedule so that children's questions can be explored.

Because scheduling will involve planning for blocks of time, it is important to schedule both horizontal and vertical blocks (Schwartz & Pollishuke, 1991). Horizontal blocks will allow the usual school organizational requirements (such as music, art, or recess). Vertical blocks will allow multiple time blocks to be connected. Now *mathematics time* and *science time* can become mathematics *and* science time. Children will have longer time periods to experiment, record, and discuss. With this system of block scheduling, language arts might be included some days when reading or writing are integrated as well.

Managing Hands-on Lessons

Hands-on lessons involve manipulative materials and groups of children. Children need to talk to each other in order to do their work. Children and teachers alike will appreciate the intrinsic motivation of discovery learning. Initially, it will seem *too exciting* and perhaps even unmanageable. Soon it will seem impossible to teach science or mathematics any other way. Hands-on lessons are *real world*. It just happens. *GEMS* (1991) suggests, "Not only is it now OK for our children to experience great joy in doing science, it is our job to make the science that we present to children compelling and fun" (p. 8). Consider the following management ideas:

1. Create a non-threatening classroom atmosphere by encouraging risk-taking and discussion. Create classroom rules with the children and allow them to make mistakes and learn from their mistakes. This behavior expectation (onus on the children) supports the risk-taking necessary for children to construct their own knowledge.
2. Design two distinct learning areas in the classroom. This allows for a *work area*, where children share, cooperate, and experiment as well as a group *meeting area*, where children gather with the teacher to discuss ideas. The work area will necessarily allow ready access to resources and materials which can easily become a distraction when it is time for discussion.
3. Organize hands-on materials in advance of the lesson. Sometimes it helps to create a specific "materials basket" for children to pick-up at the beginning of the lesson. It is also very helpful to have the materials stored so that children can gather their own materials. They can develop a great deal of responsibility in monitoring their own learning tools.

4. Arrange the children in cooperative, heterogeneous groups. This gives children the opportunity to peer teach, to clarify their ideas, and develop better problem solving strategies. Job assignments help cooperation. It is easier to work together when each person has a meaningful job.

Organizing Materials and Resources

It is most convenient to have the hands-on manipulatives and resource materials right in the classroom. In fact, Kyle (1985) reported that when teachers do not have such hands-on mathematics and science materials collected and organized in their classrooms, most science is taught by lectures or question-and-answer techniques based on district selected textbooks. In hands-on learning, the textbook becomes one of many resources. Using many resources allows children to read, write, and talk about connections across investigations in their inquiry. Consider the following organizational techniques:

1. Make the learning materials accessible to children. One primary teacher describes her materials philosophy and management:

   > I like to see children being active participants, using hands-on materials. It takes a lot of work to have that kind of a classroom set-up. My classroom always looks messy because I've got so much stuff out all the time, but it's all stuff that the kids are working on or things that children can go and use at any time. I don't have anything hidden away in cupboards for fear of it being broken. So, it looks messy and it is messy but it's an "our classroom" environment as opposed to a "my classroom" [environment]. (Thomas, 1995, p. 113).

2. Check out a "class-sized box" of trade books from the school library. Make arrangements with your media specialist to keep the books in the classroom for the duration of your unit. This allows frequent, easy access for your children.
3. Integrated lessons require more than one text book. It is no longer possible to follow the teacher's manual. It is necessary to construct a new lesson sequence—which will no doubt change with each group of children. Think about accessing curriculum materials that support the integration of science and mathematics—such *as Activities that Integrate Math and Science* (*AIMS*) and *Great Explorations in Math and Science* (*GEMS*) which are reviewed later in this chapter.

Connecting Activities and Projects

The following list suggests ways in which activities and projects might lead into one another, or take place simultaneously:

1. Some activities easily lend themselves to a learning center activity. For example, children could begin to observe the behavior of a variety of liquids in closed plastic containers at a learning center for a few days before they observe and discuss them as a class.
2. Consider that some children have the skills necessary to complete an independent study over an extended period of time. *End product* goals will help bring closure to this kind of learning. Perhaps a few children would like to conduct an in-depth, observational record of the class aquarium. The record could include illustrations of fish movement and plant changes as well as record the changing snail population numbers or plant measurements.

3. Activities may be small group or large group and usually take one or two days to complete—let the students' interests and work skills be your guide. Multiple small group activities can operate simultaneously under the supervision of volunteer parents willing to share their expertise and time.
4. Careful class scheduling will allow multiple activities to go on simultaneously. Some children will be working on open-ended activities in learning centers while others are working on an independent project with a specific product in mind. For example, children might have the opportunity to sort and classify a variety of objects in one center while others are drawing or gluing objects on a Venn diagram to demonstrate the unique or shared characteristics of selected objects.
5. Student journals can combine pictures and writing to record the learning for each day. These can help children, parents, and teachers to see the learning connections. For example, a journal entry illustrating magnetic attraction not only guides student thinking but also helps teachers to recognize student learning, and helps parents to understand the learning-rich opportunity of a playful activity involving a collection of various magnets and a box of *junk*.

Developing and Managing Assessment

Assessment is a challenging part of integrated teaching. Individual assessment is difficult when children work in groups. In addition, children greatly enjoy integrated learning. Therefore, teachers might worry whether children are really learning or simply playing. However, assessment is a vital part of integrated teaching. It records the experience of two or more subject areas during one instructional time block. Consider the following ideas:

1. Diagnostic evaluation or a needs assessment helps to define the individual learning needs of a class of children. This information will help to determine heterogeneous group assignments and to measure developmental growth.
2. Formative evaluation involves the collection of observations and work samples over time to show learning progress.
3. Observations can be guided by a checklist of behaviors and skills based on the national mathematics and science standards.
4. Summative evaluation requires consideration of specific work samples, collected observations, and test results. This will present evidence of growth with more specific times, commonly documented at the end of a learning cycle, event, or task.
5. Consider communication with parents or guardians. Integrated curriculum is a *new* idea to parents. Enlist their trust by letting them know about the richness of the *new* mathematics and science experiences with integration. Host a parent night and involve parents and children in scientific problem solving activities together. Think about *backpack* activities—ziplock activity bags that can go home in students' backpacks—and include hands-on materials and directions for family explorations. Involved parents are supportive parents.

McDonald and Czerniak (1994) suggested that, "Beginning to work with an integrated approach to learning is not unlike swimming with sharks. It's difficult! It's frightening!" It is also important to start slowly, and watch for the significant learning in your classroom. As Schwartz and Pollishuke (1991) suggest: "The key to planning an integrated, child-centered curriculum is balance—a balance among large group, small group, and individual activities, a balance in curriculum and content areas, and a balance between teacher-directed and child-initiated experiences" (p. 49).

Examples of Integrated Curriculum

This section describes two exemplary examples of integrated curriculum programs: *Activities that Integrate Math and Science* (*AIMS*) and *Great Explorations in Math and Science* (*GEMS*). Teachers can adapt these integrated mathematics and science programs to their needs. These curriculum materials encourage hands-on exploration of science and mathematics concepts and related mathematics applications. Each model can stand alone as integrated mathematics/science curriculum, be added to a district curriculum as extension activities, or serve as a model for teachers and curriculum developers who want to create their own integrated curricula. Though there are some differences in the format of the *AIMS* and *GEMS* materials, together they represent the "state of the art" in integrated elementary math and science curricula that incorporate other content areas.

Activities that Integrate Science and Math (AIMS)

AIMS began in 1981 as a small project for eighty teachers funded by the National Science Foundation at Fresno Pacific College. This successful project gave rise to the *AIMS* Education Foundation in 1986 as a nonprofit, independent organization located on the campus of Fresno Pacific College. Extensive research and development, combined with a nationwide staff development team, has earned *AIMS* a national reputation for its leadership in the development of an integrated mathematics/science curriculum. A quality staff development program supports successful *AIMS* implementation in more than twelve thousand schools.

The *AIMS* Foundation publishes thirty-nine activity books (all in English and some in Spanish), a magazine/newsletter, and a variety of additional resource books. *AIMS* also provides support materials such as data organizers, charts, classroom laboratories, and individual mathematics/science manipulatives. These materials, developed for grades K-9, are available from *AIMS* Educational Foundation, PO Box 8120, Fresno, California, 93747-8120, (209) 255-4094.

Philosophy and Design

The *AIMS* Model of Learning accommodates the needs of a broad range of learning styles. The *AIMS* Model guides children through an appropriate balance of experiences and provides a more accurate understanding of the nature and interrelationships of mathematics and science. Children "work as scientists" in each of four environments to develop essential skills in a meaningful context. In the *AIMS* Model of Learning, children study and interact with the real world in hands-on investigations. They collect, record, and interpret data; develop graphic or pictorial representations to communicate data; and engage in higher-order thinking processes of hypothesizing, inferring, and generalizing. The theme of unifying mathematics and science both permeates and underscores the purpose of *AIMS*. This integration allows teachers and children to have meaningful experiences in the classroom that parallel those in the real world.

AIMS activities do not require expensive, sophisticated equipment. Most activities depend on materials commonly found in schools (like rubber bands, paper clips, straws, balls, and rulers) or cheaply purchased at the grocery or hardware store (like nails, plastic bags, fruits, vegetables, string, and tape).

Primary activity books include:

Primarily Physics, *investigations in sound, light, and heat.*

Cycles of Knowing and Growing, *explorations of the changes common to living systems and predictable patterns of growth.*

Primarily Earth, *explorations of Earth, rocks, soil, water, clouds, and air.*

Primarily Plants, *investigations with seeds, light, stems, leaves, toots, and spores.*

Bats Incredible, *experiences in the concepts of adaptation, interaction, and diversity of bats, caves, and the aerodynamics of flight.*

Seasonal books include:

Glide Into Winter, Spring into Math and Science, and *Fall into Math and Science* which include seasonal science activities reflecting the joy and wonder of the seasons.

Sense-able Science: A Primary-Grade Example

Sense-able Science (Gosset, Delono, Kammer, Welk, & Wood, 1994) is a K-1 *AIMS* activity guide for the exploration and discovery of the five senses. Children engage in observing, sorting and classifying, comparing and contrasting, collecting and recording data, interpreting data, applying and generalizing, and communicating while they explore their five senses in a developmentally appropriate manner. These hands-on activities help children realize how they use their senses to explore their surroundings, that senses are most often used in conjunction with each other, that sensory perceptions can stimulate emotions and feelings, and that different senses provide different information. Mathematics concepts are embedded throughout the activities. Children apply counting, numeration, whole number operations, and identify equalities and inequalities throughout the science experiments. They use measurement in the cooking experiences, geometry and spatial sense while studying the shapes of beads, and the clock as a measuring tool. Experiments require children to collect and record data in charts, graphs, and Venn diagrams. Additionally, this activity book includes music and poetry as well as literature connections. The poetry and words to the songs are included in the activity book; and an audio tape (with a musical score) is also available for purchase.

Sense-able Science could be used as a thematic unit. Activities would fill two to three weeks of combined science, mathematics, reading, and language class sessions. The activity book contains approximately six activities about each of the senses. A few of the activities include:

See the *Light, in which children create "peep boxes" to discover that our eyes need light to see objects.*

Shape Search, *in which children sort and classify shapes without using their eyes (blindfolded).*

Eggs-tra Special Scramble, *in which children become aware of how the sense of taste is affected by the sense of sight.*

Designer Ears, *in which children discover how the shape of the outer ear contributes to its effectiveness in collecting sounds.*

Assessment is integrated into learning for each activity. Assessment suggestions such as journals, further investigations, oral interpretations, and performance-based tasks measure the student's conceptual understanding. These assessments measure conceptual understanding (depth of knowledge) rather than facts or vocabulary (quantity of knowledge).

Great Explorations in Math and Science (GEMS)

Great Explorations in Math and Science (*GEMS*) is a growing resource for integrated mathematics and science activities. Originally developed at the Lawrence Hall of Science, *GEMS* has been tested in thousands of classrooms nationwide since 1984. Now, fifty *GEMS* teacher guides and handbooks integrate mathematics with life, Earth, and physical science for children in preschool - high school. A *GEMS* guide book includes an "Introduction" to the guide, an "Overview" of the guide, "What you Need" and "Getting Ready" sections, followed by step-by-step presentation instructions for 3-7 sessions or activities. Lessons are based on the guided discovery approach and utilize easily obtained and inexpensive materials. *GEMS* activities, with clear directions and content information, allow teachers without special background in science and mathematics to be successful in hands-on, discovery teaching. These are available from the Lawrence Hall of Science, University of California, Berkeley, CA 94720-5200, (415) 642-7771.

Philosophy and Design

The *GEMS* activities first engage children in direct experience and experiments before presenting explanations and principles of concepts. The learning objectives, concepts, science themes, and mathematics strands can be flexibly related to any science and mathematics curricula. Each guide book also suggests ways to extend the activities across the curriculum into language arts, social studies, and art. *GEMS* activities are designed to captivate children's imagination while illuminating scientific concepts and methods. With an emphasis on success and teamwork, *GEMS* activities give children a positive experience in science and mathematics that builds student confidence. *GEMS* activities encourage cooperative teamwork in exploring a problem or solving a mystery and build critical thinking skills. Assessment is embedded within the *GEMS* activities and samples of model student work are included throughout the guide.

The *GEMS* approach focuses on building a positive attitude toward science and an understanding about the nature of science as a venture in questioning, investigating, cooperating, and making sense of the world. Activities allow children to simulate scientific endeavors, to hold scientific conventions, and to construct increasingly accurate models of nature and the world.

Primary guides include *Animal Defenses*, a comparison of dinosaur defenses and those of modern-day animals; *Buzzing a Hive*, a construction and dramatization of the complex social behavior, communication, and hive environments of honey bees; *Ladybugs*, an exploration of the body structure, symmetry, life cycle, defensive behavior and environmental role of the ladybug; and *Frog Math*, a take off on the well known "Frog and Toad" stories with button sorting and classification, button designs and button graphs, and an experiment in probability and statistics. A new *Once Upon a GEMS Guide: Connecting Young People's Literature to Great Explorations in Math and Science* lists several hundred annotated student books and suggests related *GEMS* guides, major mathematics strands, and science themes.

Focusing on Liquid Explorations: A *GEMS* Example

Liquid Explorations (Agler, 1986), a *GEMS* guide for K-3 children, provides engaging experiences in physical science for primary children as they observe and experiment with various liquids. The time frame suggested for *Liquid Explorations* is five class sessions. Suggested time spans for session activities range from 15 to 60 minutes each. In the first activity children play a classification game with different colors and types (such as thick, clear, or sticky) of liquids. Next they observe, compare, and record the way food coloring moves through different liquids. In the third activity children discover that some liquids mix and others do not as they observe the behavior of a drop of water and a drop of oil, make an "ocean in a bottle," and create a secret salad dressing recipe. In this early childhood experience in physical science, vocabulary words and scientific explanations are limited to descriptions children can see. This hands-on exploration and guided discussion lays the groundwork for the later introduction of abstract terms such as density, surface tension,, and miscibility.

The concept of the properties of liquids is the focus in this *GEMS* guide. Children will practice the science skills of observing, comparing, classifying, recording, and drawing conclusions. Mathematics skills include logic, patterns, measurement, and numbers. In a major science themes approach, children will consider systems and interactions, stability, patterns of change, structure, and matter.

Conclusions

Teaching science using an integrated approach offers a way to follow current reform in mathematics and science education—to be simpler (in details) and more sophisticated (in the nature of ideas). It offers the opportunity for a child-centered focus in teaching and learning which supports the inquiry-based learning of constructivism—hands-on experiences to increase meaning and conceptual understanding. Integrated teaching necessarily involves multiple resources and unique connections—fresh, new curriculum connections invented by children and teachers together. Integrated teaching involves a reorganization of lesson planning, instructional materials, and learning assessment. *GEMS* (1991) shares the response of one teacher to integrated teaching:

> I wasn't too sure what to make of themes and "the thematic approach," until I saw a few practical examples, and then I started thinking of things I might do, favorite books of mine that would fit into a particular theme, etc. As soon as that happened, I got excited about how much opportunity there is for creativity and the interweaving of interesting connections, and new ideas started cropping up all the time. (GEMS, 1991, p. 26)

Reviewing models of mathematics and science curriculum such as *GEMS* and *AIMS* can help to build confidence and generate new ideas about how to develop mathematics and science connections in an integrated format—to section blocks of the teaching day to allow for maximum opportunity for mathematics applications to bring science alive. As teachers understand other issues, such as management and assessment in integration, they too will benefit from a more motivating approach. The projects, activities, and centers in this book are examples of integrated curricula that address new ideas, meaningful content, management and assessment, and community involvement.

There are still many questions to be answered, such as: Can student motivation toward learning of selected mathematics concepts be improved by integrating science and mathematics with other content areas? Can student knowledge and understanding of selected science and mathematics concepts also be improved? Does integrated learning increase student perception of relevance between what they are learning and their own lives? Is integrated teaching more or less effective for children of differing characteristics such as socioeconomic status, achievement level, or attitude? Does integrated teaching enhance constructivist theory? What are the integrated science and mathematics professional content skills? How can elementary teachers best be prepared to design and support integrated teaching? A quote by Greenberg (1993) begins to address these questions:

> Interdisciplinary education is not the only answer for the woes facing American schools, but it does introduce a fresh way to provide viable and exciting instruction in the classroom. A national network of teachers working in interdisciplinary models, sharing resources, strategies and activities, could be an extraordinary impetus for the improvement of American education (p. 12).

About the Author

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Chapter 3

Overcoming Limitations

Karen Sullenger & Mark Holland

Primary classrooms are busy places. Teachers and young learners alike are constantly engaged in activities. Teaching science in the primary grades has its own challenges. Even though using activities, projects, and centers to teach science in the primary grades can be very rewarding for teachers and children, there can be difficulties related to children's experiences and capabilities, differing instructional approaches, school structure, and available resources. In this chapter we provide an overview of the difficulties a teacher can face in planning and implementing activities, projects, and learning centers, and we offer ideas and strategies to overcome limitations.

Children's Experiences and Capabilities

Children enter the classroom full of ideas and experiences. Researchers interested in the processes of conceptual change contend that the prior experiences, beliefs, explanations, and capabilities that children bring with them to the classroom can act as barriers, making it difficult or impossible to understand scientists' explanations (e.g., Driver, 1995; Osborne & Freyberg, 1990). From the many factors that may act as barriers to children's understanding of science, we have chosen to focus on six: children's prior conceptions, language, cultural beliefs, learning styles and capabilities, children's learning difficulties, and gender.

Children's Prior Conceptions

Before children enter school, they construct descriptions of the world around them that may be different from the descriptions scientists use. Using interviews and observing children solving problems, researchers from a number of countries are studying the kinds of explanations children develop about their world. One thing seems clear: even young children are likely to hold on to their own explanations about the world despite what they are told in school. Unless children are faced with experiences that challenge their conceptions, they are unlikely to change their models of how things work or accept alternative explanations and descriptions as useful or important.

For example, what is a bounce? Young children are likely to say a bounce is what happens when something hits the floor or wall and doesn't break. With more years of schooling, the preservice teachers in my Introduction to Teaching Science course describe a bounce as an object changing direction when it hits another object and that pieces of broken objects can bounce. When pushed, they say that even if it is only millimeters the object must leave the floor or wall to be considered a bounce. Both of these descriptions are different from the current scientific description.

Within the science community, a bounce is described in terms of a collision. A collision occurs when any two surfaces come into contact; collisions are either elastic or inelastic. Why do scientists find it easier to think of the contact of one object with another as a kind of collision? Most likely, because they explored more kinds of objects contacting one another than a typical person would encounter in their own environment.

Another example of a problematic concept common in the primary grades is the description of people as animals and trees as plants. In our everyday language and actions we do not talk about or treat people the same as our pets or animals that live around us. We talk about trees

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differently than grass or flowers or "plants." On the other hand, scientists think of living organisms as being in one of five categories called kingdoms. People, according to scientists, are animals; trees are categorized as plants.

One outcome of these differences in descriptions is that science appears to be "unnatural." When we teach science as the way the world works, science descriptions carry a sense of truth. What happens to the learners own explanations of the world? If the science descriptions are in conflict with explanations held by the child, affirmed by authority figures in the child's life, or broadly accepted by people in the child's culture, we may create conflict within the child, especially, if we treat the science description as the truth and require children to give the scientist's answer.

A second outcome, for children who cling to their own explanations, may be a feeling of disenfranchisement. Children may begin to separate school explanations and home explanations. Or children may begin to believe they are unable to learn science; it is just too difficult to figure out. Still others may reject the science explanation as not plausible and accept instead their own, or their community's, explanation.

Ideas to Try

Exploratory activities designed not to teach but to explore children's understandings may provide useful insight. We have tried slides, activities, pictures, stories, and demonstrations to create a context to initiate student talk. We find this approach encourages children to talk without a fear of being put down for their ideas and builds confidence. We use the information gathered from such activities to revise and/or refine my units and lessons.

The Teaching of Science by Wynn Harlen (1992) and *Learning Science* by Roger Osborne and Peter Freyberg (1990) provide both the research and classroom ideas for taking children's prior beliefs into account.

Language

Language can also be a barrier to learning science. First, science uses very specific meanings for terms and invents new words when old terms no longer serve their purpose. Second, studying a field of science often requires learning more new vocabulary than would be introduced in a second language classroom. Third, the learner's ability to communicate ideas and understandings is, perhaps, the greatest barrier at the primary level.

Alternative Meanings

Learners may develop an understanding of the meaning of certain words that is different than the scientists' meaning for these words. People outside the science community and scientists themselves give these same words other meanings or use them in other ways resulting in slight nuances to the original meaning. These alternative meanings can make understanding and accepting the scientist's use of the word or term difficult. For example, the concepts living and non-living are commonly introduced in the primary grades. The meaning of the terms living and non-living are confounded by the meaning of the terms alive and dead. Interviews with primary-aged children reveal that many of them consider cars, batteries, and fire as living and not unreasonably so. In everyday language we describe those and other non-living objects as being alive, e.g., a live wire or the fire "came to life" when we added wood, or as having died, e.g., the car or battery died. Young learners also have trouble accepting that wood for the fireplace, bones that their dogs chew, and leather gloves are categorized by scientists as living.

Community is another concept often introduced in the primary grades. Scientists define a community as the interaction of living organisms within a bounded system. A community could vary in size from a drop of water to a pond, from a log to an entire forest, depending where the boundaries are established. Within the general culture, communities are determined by groups of residents who have some common identity. Communities in this sense focus on the activities and needs of human beings. A biologist on the other hand treats the human being as one species among many, with a specific habitat (address) and niche (job/function) within the community.

A final example, is the concept of force. We talk about force as one aspect of a field of influence surrounding objects. That is, a force field is a complex of pushes and pulls. However, the everyday use of the term force includes such phrases as, "I was forced to go to bed without my dinner," "Someone forced their way into the house," "My Mom works on the police force," and in the movies, "May the force be with you." Young learners must grapple with a range of meanings for most terms. How do they decide which is the "right" meaning or which meaning is "right" in which situation? These distinctions may be some of the most challenging aspects of learning science, and contribute to children's beliefs that science is unnatural.

Ideas to Try. Young learners catch on quickly to people's reactions, verbal and nonverbal, when they use terms incorrectly. They learn to differentiate between meanings in different contexts. However, children seldom interact with scientists. Consequently, they have little context in which to determine scientific use and meaning of words. Teachers can create opportunities to practice using science language in authentic science contexts or in conversation with scientists. The Internet makes this even more possible today.

New Vocabulary

In addition, scientists use vocabulary that is not used in everyday language. One study indicates that over 750 new science related terms are introduced from kindergarten to grade six (Mastropieri & Scruggs, 1991). In addition, some young learners require more time than others to develop reading and writing skills. If they are expected to understand that the meaning of words can change in different contexts, the task of reading and writing can be that much more difficult.

Science language can be even more challenging for ESL learners, especially if science words have different meanings within the school or community. When children are learning the school language as a second or third language, the child's intellectual, social, and physical capabilities may be masked. Research indicates that language can interfere with children's test results and interactions between children and their teachers (Mastropieri & Scruggs, 1991).

Ideas to Try. Identifying and talking about the uses of different vocabulary and use of the terms in different contexts may be enough to help learners distinguish among meanings. Practice in the use of science language allows teachers to monitor children's understandings. Additionally, practice will help children clarify the conceptual meaning behind the word.

Language to Express What They are Able to Learn

We believe there is a gap between our ability as learners to observe and think and the language available to communicate our observations and thoughts. In the Introduction to Teaching Science course, we use a box with objects inside. One preservice teacher is blindfolded and asked to describe the contents of the box using only statements of fact. The other preservice teachers must then infer the number of objects in the box and name them. In class, we define observations as information gathered using the five senses directly or using tools or instruments to extend the senses. Facts are defined as our best description of what we observe. Inferences are defined as information based on and supported by observations, but that cannot itself be observed. Unfailingly, the blindfolded person could "name" the object, but has great difficulty finding the language, the vocabulary, to describe them so that others can name them. This kind of response demonstrates there can be a gap between a child's ability to observe, create meaning, and to convey his/her observations.

Exploring the properties of objects is a common primary science concept. Some of these properties are color, smell, shape, size, weight, distance, texture, taste, sound, flexibility, and pattern. Young children may find it difficult to be a "successful" observer in each of these areas if they lack the vocabulary to capture and share their observations. For example, children may know there is a difference in sounds or color, but lack vocabulary to differentiate particular colors or sounds. It seems this gap is even more problematic when learners are unable to articulate ideas which they "feel" they know. For example, we have seen primary-aged learners unable to defend their choice of solution or explain how they decided on an answer beyond a shoulder shrug or "I don't know." We believe children are really saying, "I know, I just don't know how to explain it."

The English language is rich in synonyms to capture nuance. When asked to develop a list of words that describe various properties, preservice teachers can list fifty or more in each category. If we want to close the gap between what young learners are able to observe and think we must provide them with ways of sharing their ideas and understandings.

Ideas to Try. One solution may be using gestures, pointing to similar objects, and drawing as substitutes for verbal or written language. The teacher can create preverbal situations that help to build children's understandings. Next, the teachers can use metaphors to develop understanding.

Metaphors can also build vocabulary and bridge the gap between thought and language. Metaphors may represent the limits of vocabulary. The learner, unable to find the right word, replaces the accepted vocabulary with a similar experience. For example, when I have children smell moth balls, they often say something like, "It smells like my grandmother's closet," or "It smells like a trunk where we keep winter clothes." One way to help develop vocabulary is to ask. "What about the closet or trunk reminds you of this smell?" Sometimes the question triggers words which the smell didn't trigger. It is also possible to use the response to provide children with new words.

How many smells do young children describe as "stink"? Providing a sensory table where children can practice inventing words to describe differences in observations like smells, sounds, and textures. The sensory table can also be used to develop relationships between sensory experiences and standard vocabulary. One way to help children develop their sensory vocabulary is to provide them with sensory experiences. A walk around the school, school yard, neighborhood, park, or farm could be an opportunity to introduce new sensory experiences and language. With these descriptions, teachers can help make comparisons with alternate science words and meaning.

Another idea is to identify potential language barriers, such as, existing vocabulary with alternative meanings to science; new vocabulary necessary to understand scientists' ideas, models, and work; and sensory and other vocabulary needed to share ideas and understandings.

Cultural Beliefs

Most of us teach in increasingly multicultural classrooms. Young learners often come to school with different explanations of the same phenomena that scientists are interested in describing. Whether from religious or cultural origins, these explanations may make accepting the science descriptions problematic. These cultural models may be considered "natural" while the science explanations are considered "unnatural" or "counterintuitive." Young learners could be "caught" between their culture and their teacher. Having to choose between explanations valued in school and those valued by their parents and/or members of their community can cause stress and perhaps rejection of one view or the other.

An example, reported by Marjorie Jannotta (1986), describes cultural differences arising from Navajo beliefs and the hands-on science approach, which encourages young learners to touch and interact with the world. When Marjorie's class found a snake, she picked it up and, while describing its life history, allowed children to touch and hold the snake if they wanted. Unbeknownst to her, the Navajo tradition forbids the touching of snakes, believing that an evil spirit will enter the person's body where the person came in contact with the snake.

The dominant culture does not always value or understand other cultures. Young children may come from local traditions that may be different from those of their teacher or schools. For example, the ways children interact in school, with their family, and within the community may be different in terms of what knowledge, measures of success, or behavior is valued.

Learners who are not successful in school receive various labels, such as, at risk, the "C" student, unmotivated, mentally, emotionally, and/or behaviorally challenged, lazy, or stupid. There is growing belief that many of these learners have styles or preferred ways of learning to which the current structure of our schools and teaching practices do not recognize or attend (Barone, 1989).

Ideas to Try with Parents

Sharing classroom science concepts and activities with parents and encouraging them to share their beliefs may be helpful. Discussing such ideas with parents and learners could be a way of honoring both explanations in the classroom. Talking directly with young learners about differences between scientists' ideas and work and the ideas and work of others, including themselves may also be useful.

Learning Styles and Capabilities

Learners make sense of the world differently; learning styles is the name given to each person's preferred way of interacting and making sense of the world. Each of us is a unique set of sensory neurons and neural systems which interact uniquely with our environment. A number of theories describing differences in learning styles have been posed, e.g., left brain-right brain, learning modalities, and multiple intelligences. These theories suggest that logical and cognitive functioning reflect a limited and unidimensional way of thinking about learning even though they are the most valued in schools. Each theory offers a different perspective of the difficulties children may have with learning, including learning mathematics and science.

Right Brain, Left Brain

The theory of brain laterality or hemisphericity describes different attributes to each brain hemisphere. The left hemisphere is described as logical or analytical with language as a medium of thought; the right hemisphere is described as being more holistic or intuitive with images and metaphors as a medium of thought. The most recent research suggests that the differences are not so definitive (Buzan, 1994; Caine & Caine, 1990). Cognitive functions seem to be located throughout both hemispheres of the brain. However, what seems consistent is the recognition that the right side of the brain deals more with rational, language-based understandings while the left brain deals more with intuitive, image-based understandings.

In addition to the challenges young learners already face in finding language to express their understandings, this theory suggests that some young learners may prefer to think in terms of *images* instead of language. The question is whether both forms of knowledge are valued in schools; the answer too often is "no."

> Both forms of knowledge can be accurate, and each form can enhance the other. Traditional, formal teaching styles are directed toward rational knowledge. Intuitive knowledge has been distrusted and dismissed in the classroom as being less verifiable and too rapid to be explained by logical reasoning. (Harlen & Rivkin, 1996, p. 9)

Science thinking is often intuitive and creative. Even so, scientists whose work evolves from such thinking struggle to find language to share their ideas using the rules of evidence and reasoning processes valued in the science community. Perhaps the reasons so many learners find science difficult are the same reasons they find school experiences difficult. As we will see with the discussion of gender as a possible barrier, the structure of science itself may be problematic.

Perhaps, what we need to teach in schools is an understanding of science as practiced by scientists, an understanding that encompasses the intuitive as well as the rational, logical thinking which currently dominates science curriculum. Such an approach would recognize and provide a place for intuitive learners as well.

Ideas to Try. Many teachers in early childhood programs already place value on intuitive thinking using drawings and invented words. Allowing young learners to revise their drawings and identify images in their drawings would be a way of substituting images instead of language to reflect their understanding. Perhaps, children could use parts or pieces of their drawings to create a storyboard explaining what they learned about the topic of study.

Learning Modalities

People prefer to understand the world relying on one or two of their senses predominately. These preferences are referred to as learning modalities or in some cases, learning styles. The four modalities most often recognized are visual, auditory, tactile, and kinesthetic. Our purpose is not to describe these modalities or alternative categories as there is much literature already available (e.g., Martin, Sexton, Wagner, & Gerlich, 1994; Renzulli, 1994; Samples, 1994). Instead, we are interested in the ways in which preferred learning modality may make learning science and mathematics more difficult.

A number of studies suggest attending to children's learning styles results in improved achievement scores and behavior (Klavas, 1994). One school, with over half the children preferring tactile or kinesthetic modalities, presented concepts first in the children's preferred learning styles, next in their second for practice, and reviewed the ideas verbally (Klavas, 1994). Science, mathematics, and other content areas needs to be more than subjects and methods. Some learner styles connect with the world less through logic than with aesthetics and feelings, through affective avenues, personal commitment, and acting (Samples, 1994).

Not all researchers are convinced that attending to learning styles will result in changes to learning, or that teachers can manage classrooms with such a variety of needs to meet. However, those that are convinced suggest attending to learning styles may be the most important determinant of children's success in schools (O'Neill, 1990).

Ideas to Try. Individual teachers could provide choices, a number of ways children could demonstrate their understanding. Centers, activities, and projects lend themselves particularly well to individualized study and multiple outcomes. The 4MAT instructional approach was developed specifically to address differences in learning styles.

Joseph Renzulli (1994) contends that learning styles are a complex combination of preferred learning environments, instructional styles, thinking styles, and expression and learning styles. His book, *Schools for Talent Development: A Practical Plan for Total School Improvement*, offers practical advice for identifying learners' preferences and designing a school-wide program for planning and teaching to the needs of learners with various preferences. The article, "Instructional Diversity," by Samples (1994) provides examples of activities for various styles of learning.

Multiple Intelligences

Howard Gardner (1993, 1995) defines intelligence as abilities to solve problems recognized as valuable within a culture. He identifies seven intelligences—linguistic, logical-mathematic, spatial, musical, bodily-kinesthetic, interpersonal, intrapersonal, and naturalistic—as starting points in the discussion and argues that there may be other intelligences or even sub-intelligences. Gardner does not agree with Piaget's or developmentalists' beliefs that there is an overarching or underlying or unifying system of knowing. Instead, he believes that knowing may be multifaceted and discrete; knowing in one area does not necessarily transfer to another.

In posing his theory of multiple intelligences, Gardner argues that "school should be to develop intelligences and to help people reach vocational and avocational goals that are appropriate to their particular spectrum of intelligences" (1993, p. 9). He contends that linguistic and logical-mathematical intelligences are most valued in schools today and that learners whose strengths are not in those areas often find school an unsuccessful experience.

Even when the spectrum of intelligences is identified, young learners can face difficulties in having their particular strengths and interests recognized. The interest and support of parents, family, teachers, peers, and the community all influence the learner's potential. Although there is growing evidence that broadening our notions of intelligence and using an activity-based versus a language-based assessment instrument provides us with better information about young learners, Gardner argues the work in this area must be considered promising but not conclusive.

Ideas to Try. Gardner and his colleagues have developed a set of "tests" which are in reality a set of activities and games called *Spectrum*. The tests developed for learners in the early years are described in Chapter 6 of his book, *Multiple Intelligences: The Theory in Practice.* Using these activities may help identify the intelligences of early learners and provide insight into developing activity series, centers, and projects that challenge their varying needs.

Campbell and Burton (1994) have developed a teaching approach which combines learning modalities (which they refer to as styles), Gardner's notions of multiple intelligences, and the belief that learners should have a say in their learning. Their unit plan provides ideas for designing and structuring activities or projects for the needs of varying learners.

Children's Learning Difficulties

Learners with special needs require carefully planned opportunities to learn in order to reach their potential. The categories of special needs or challenges include children who are physically, emotionally, socially, and intellectually challenged as well as gifted learners. Even so, there is evidence that preschoolers and children in primary grades are able to work together regardless of their abilities. The diversity of abilities seems to be less obvious to children of this age (Chomiciki & Kysela, 1993).

Integrating all learners into the classroom is a reality in most schools. The activity-series, activity-center, and project-based teaching which are the focus of this book are generally described as child- or activity-centered teaching approaches. However, children with certain disabilities may have difficulty in unstructured learning situations. Consider the range of instructional approaches available. The two extremes of this range are described as teacher-centered (content-centered), which is generally very structured, and child-centered (activity-

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centered), which is often very unstructured.

Teacher-centered instructional approaches are generally textbook-based, and the primary mode of communication is verbal; the curriculum is teacher-centered; and children's work is evaluated through written tests focusing on factual recall. There is a high demand on vocabulary learning and covering information with little active exploration of ideas; activities are generally used for demonstration and confirmation.

Child-centered approaches focus on depth versus breadth with reduced emphasis on vocabulary and terminology requirements and more emphasis on skills such as predicting, classifying, and observing. Advocates of these approaches use alternative assessments to paper and pencil tests. Science and mathematics instruction is delivered using both these kinds of approaches. Further, there is evidence that teachers are "more receptive to mainstreaming children with disabilities in science classes than in any other subject area" (Scruggs & Mastropieri, 1993, p. 15).

Scruggs and Mastropieri (1993) suggest that children with particular learning challenges may do better in one approach than another. For example:

- Children with language difficulties will do better in activity-oriented approaches, but will still need to deal with vocabulary demands. Adapting curricula using audio tapes, visual cue cards with pictures, peer or tutor assistants, and cooperative learning techniques may help.
- Children with cognitive difficulties may have more problems with activity-oriented instruction than content-oriented instruction. Reducing the complexity of the tasks in either approach would reduce these problems and help with the development of learning complex concepts. The "open-ended" discovery approach often leaves these learners behind as they do not readily "catch on" through tasks. Coaching and carefully structured questioning strategies help these learners cope with activities.
- Children with psycho-social functioning that results in aggressive or disruptive behaviors may benefit more from a structured than an activity-centered approach. Sometimes placing these learners in a group by themselves with adult supervision works well. However, young learners who are shy or withdrawn or have low attention spans may benefit more from activity-centered approaches with groups who are considerate of these children's needs. As we discuss later, safety using science equipment and materials is of primary importance for all learners and may be of special concern for learners who have difficulty working independently.
- Sensory-physical functioning may limit a child's ability to interact with science and mathematics manipulatives unless such materials are designed specifically for such limitations. Textbooks and language based activities could also be difficult if adaptations are not provided.

The consequence of work with children who have learning difficulties is that neither approach *alone* adequately meets the needs of all children.

Gifted learners can be as easily ignored as children with learning difficulties. The currently recognized broader definitions of giftedness make it easier to identify gifted learners and provide more challenging learning activities. Gifted or talented learners are not determined solely by academic achievement, but by their creativity and ability to stick to a project and see it through. Gifted learners are not universally gifted in everything they try but most often gifted only in particular areas. Finally, current thinking supports in-class approaches to challenging gifted learners rather than pull-out or special programs that isolate these children from their peers (Renzulli, 1994).

Renzulli (1994) argues inclusive education is about all learners recognizing and celebrating their talents. Many of the activities and teaching approaches described benefit all learners, including children who are often excluded from traditional curriculum approaches.

Ideas to Try

Renzulli's 1994 book, *School Is for Talent Development: A Practical Plan for Total School Improvement*, contains descriptions for activities and teaching strategies that benefit all children. Programs like *Talents Unlimited* and curriculum compacting develop thinking skills for not only the gifted, but benefit all learners as well. Participants of a summer institute on educating gifted learners reported they were pleased by the way these teaching strategies benefited all their children (Cashion & Sullenger, 1996).

The first author in this chapter, Sullenger, found that working with a school's resource person was a helpful way to identify the kinds of challenges facing the children in each class. Centers, activity series, and projects could be modified using tape recorded instructions, teacher aides or parent volunteers, individual envelopes with special directions, or choice to be either more or less structured depending on the needs of each child.

Gender

Some describe the under representation of girls in science careers and school science as an outgrowth of our educational systems, cultural expectations, and social attitudes and stereotypes (Shepardson & Pizzini, 1991). Differences in the roles and interests of girls and boys begins at home and in the community, before learners enter school. Cultural and social biases about what and how to play, what to be interested in and pursue, and acceptable behaviors including acceptable family and community roles are modeled early in children's lives. Teachers' expectations are influenced by their own social and cultural environments and may be unaware of differing cultural and social expectations.

The perception that science is a male experience is perpetuated in other ways as well. The stereotypical view of scientists, as white males in lab coats surrounded by test tubes and chemicals, dominates much of the visual world describing science. Although textbooks are more careful to include pictures of scientists from different gender and cultural groups, most movies, cartoons, and magazines are not so forward thinking. Another problem is boys continue to receive more of the teacher's attention than girls (Haggerty, 1994).

Science itself is charged by some as being masculine. As an endeavor, science has been dominated and constructed by men's experience and represents a masculine world view. "Feminist scientists argue that bringing a more holistic and personal approach to science will enrich science, making it more accessible and more valid for all" (Haggerty, 1994, p. 7).

Ideas to Try

A colleague was asked to observe the way we interacted with children in a course, especially focusing on patterns of questioning, calling on, and responding. Their feedback was helpful in realizing that we tended to challenge male's responses more than women's. We wondered if "kindness" implied seeing women as less able to defend their ideas.

Identifying goals to establish more gender equity in the school and in science may be helpful. Gender equity is distinguished from equality in that each person may require different rather than the same treatment to meet their needs.

Instructional Approaches

Instructional approaches are often described on a continuum with teacher-directed approaches anchoring one end of the spectrum and child- or learner-centered approaches anchoring the other end. The instructional approach selected by the teacher may limit what can be accomplished using centers, projects, and activities.

Every teaching approach has its share of critiques. For example, the theme or project approach often integrates science within a larger program. The play-based approach usually does not emphasize the explanations and ideas of science as much as the processes and skills. Constructivist approaches, when linked with teaching for conceptual change, emphasize beginning with an understanding of the learner's prior conceptions but working to replace these conceptions with scientific understandings. In each case, the teacher recognizes and plans for science experiences, but the child may not be involved in talk about scientists' explanations as much as articulating their own explanations or developing skills. The question, "What counts as understanding science?" becomes critical. One concern many elementary teachers have is whether they should focus on children being able to articulate and defend their ideas or how well the children's explanation matches the scientist's.

Another critique is of discovery, guided discovery and similarly structured approaches. Children learn to "play the game" of doing investigations. Driver (1985) contends that:

> [Children] are quick to recognize the rules of the game when they ask "Is this what was suppose to happen?" or "Have I got the right answer?" The intellectual dishonesty of the approach derives from expecting two outcomes from pupil's laboratory activities which are possibly incompatible. On the one hand pupils are expected to explore the phenomena for themselves, collect data, and make inferences based on it; on the other hand this process is intended to lead to currently accepted scientific law or principle. (p.3)

Harlen (1992) argues that observations are theory dependent, children make observations and inferences based on beliefs they hold. Further, without some framework or purpose there is no basis on which children can make useful observations and inferences. Practically thinking, Harlen points out, "the problem is that children's manipulations and measurements are too rough in many cases for exact relationships to be found from experimental work" (p. 47). Children are left with having to be told the expected or "right" outcome.

Approaches that provide children with problems to solve or questions to answer, such as inquiry, problem-solving, or resource-based teaching, are criticized in that children may be learning more about technology than science, especially at the primary level. "Making a bridge from paper, a candle clock which triggers an alarm, a sign which can be seen at night—will all involve the application of scientific ideas, but, perhaps, not the development of these ideas if the activity stops at the point of solving 'the problem'" (Harlen, 1992, p. 47).

Such approaches were developed to motivate learners and create an interest in science and mathematics. However, if children do not see the problems as problems or have no incentive to solve the problems the approach fails. To address this concern instructional approaches using children's questions as a beginning point emerged (e.g., inquiry and interactive teaching or children's questions approach).

Harlen (1992) argues shifting the focus from teacher initiated problems to child initiated questions also shifts the instruction from problem solving to problem posing. Even collecting and choosing children's questions to create a community of learners and avoid the vague and often untestable nature of children's questions can become problematic. Children view the main task as coming up with questions rather than reflecting or studying the object or idea they are asking questions about.

Neither teacher-directed, child-centered, or approaches somewhere in between, are problem-free. Approaches that ignore the best of other approaches may deprive some children of developmentally appropriate practice, that is, the variety they need to learn. Teachers must decide on instructional approaches that meet the needs of their learners and with which they are comfortable.

Ideas to Try

Shifting the responsibility from the teacher to the child at varying rates, that is scaffolding each child's learning either individually or in small groups, may provide a way to include a child's ideas and questions while searching for a scientist's understanding.

Including a mix of structured and unstructured activities, projects, and centers as well as teaching approaches could also help. Assigning children to activities, centers, and projects or including them in group learning that best match their learning preferences and abilities is another possibility.

Limitations to School Structure

There are various factors within the school itself that could limit your introducing children to learning through activity series, projects, and activity centers. These include staff members and their support of these teaching strategies; the physical structure of the classroom; the resources available at the school; and the composition of your class. This section considers each of these factors and offers ideas to use when making your plans to change the style of learning in your classroom.

People Within the School Structure

As early as possible you should assess the position of colleagues and parents regarding the use of these teaching strategies within the classroom. These strategies will change the focus for student learning to one which places the child in greater control of learning through experiences that are activity based and are authentic, i.e. real world experiences that are meaningful to the child. Although centers have guided activities, they provide more opportunity for children to follow a personal line of investigation. A good description of centers, activities, and projects are available in a number of sources, as well as throughout this book (Cowles, 1992; Patillo, 1992; Sherman, 1992).

In order to assess others' positions, ask yourself: Is learning science through practical investigation already practiced at the school? Do people show an interest in this approach? How should you begin introducing changes that might be a break from tradition? Do some of your ideas require approval of administration and cooperation from colleagues?

There are several people key to successful development of child-centered learning process based on practical tasks: As educational leader in the school, the principal should understand the goals and methodology of this learning environment and be helpful in overcoming the challenges you meet along the way; teaching colleagues can also be very helpful, especially if your ideas provide an opportunity for professional development; and parents will also enjoy participating if they understand the goals and reasons for change. Because your classroom will undergo some physical changes and there exists the possibility that "messes" will be created, it is also suggested that you involve the janitorial staff as early as possible.

If some colleagues are using this approach, or are receptive to it, working closely with one or two other teachers can be very rewarding and a source of support in times of doubt (Himel, 1993). Possibly teachers in neighboring classrooms may wish to share the experience. There is no substitute for good planning; obstacles and problems can be avoided by cultivating a cooperative approach to this alternative method of structuring children's learning. By having several members using a "team approach" challenges are met and successes are enjoyed in a creative way.

For Starters...

1. Assess the position of colleagues and parents regarding child-centered learning. It is very important to inform and involve parents.
2. Check with the staff to see who might assist you or become a mentor.
3. Plan well and plan well in advance. Try to anticipate obstacles and be ready to solve them (Gough & Griffiths, 1994).
4. Try to form a team that will share the tasks associated with making the required changes. This team might represent administration, teachers, and janitors.
5. Several sources are recommended for general reading on "getting started." (Barbour & Seefeldt, 1993; Cowles & Aldridge, 1992; Gough & Griffiths, 1994; Patillo & Vaughan, 1992; Sherman, 1992; Taylor, 1993).

Classroom

When planning for science learning through practical investigations one must assess the physical limitations of the room. What is its shape? What floor area does it offer? How many walls have windows? Will heaters block the placement of centers? Is it possible to locate practical tasks within the room for extended periods and retain ease of movement for children and also periods of undisturbed study? What is the condition of the floor; is there carpeting or can spills be easily cleaned up? Are there places in the room where results of student investigations can be displayed? Is there space to store individual projects? Although a quick survey will answer some of these questions, others will require that you plan placement of practical tasks with care and consideration in order to make efficient use of space (Taylor, 1993).

Another serious consideration is that of storage space. This seems to be in limited supply in every school and development of practical investigations may require more equipment and materials to be stored. As the whole staff becomes part of developing child-centered learning, possibly the challenge of storage space may be solved in a cooperative manner whereby previously "off-limit" areas could become available for general use. Shared use of storage may also mean shared use of equipment, thus optimizing limited budgets. When multiple uses are made of resources, it is suggested that a good system of reserving, replacing, and maintaining the equipment be developed.

When you survey the room during advance planning, one should also check the suitability of furniture for the intended uses. Does the room have desks only? Are there tables; are they the same height; do they have good stability? Are the surfaces of the desks adaptable to practical tasks? Will children be able to work comfortably both sitting and standing at these centers? Can the tables be placed, and their height be adapted, for children with special needs? If the furniture is not easily adapted, perhaps exchanges may be made with other rooms. Larger working surfaces can be made by using sheets of plywood cut to fit and clamped/bolted to two desks. It might also be possible to construct a small vertical surface at the back of the table to allow information/charts to be posted at the center. Note: One should take care not to block the teacher's field of view from a supervision perspective.

Another consideration is the placement of tasks that require a water source. Does the room have a sink or must you bring water from some other location? Can you limit the volume of water needed to service the center and not compromise the activities? Working with smaller volumes eases the task of transportation, dumping, and reduces the problem created by spills.

School

There are various factors in the school that may limit using science and mathematics child learning centers. Children who are actively engaged in practical investigations will be moving both inside and beyond the classroom. The location of the classroom within the school will determine if movement of your children will disturb those of neighboring classes. You should expect that active investigations will cause higher noise levels as learning takes place; these need not be mutually exclusive!

Before embarking on this approach to learning, it is advisable to determine how supportive the principal and colleagues will be despite the degree of student movement. Creating an interest and degree of cooperation from colleagues will help reduce potential friction. It is important that you understand what you want to achieve and show that you have prepared yourself through research (Taylor, 1993).

Another important consideration regarding location of the classroom is its ability to support growing of plants with sufficient sunlight and heat. Rooms on the north side of a building, those with very little natural light, or those with tinted glass have a significant disadvantage. You may need to provide a "growlight" or arrange for plants to be placed in an alternative but secure location. The object of maintaining plants is often for children to observe the effect of different growing conditions, to measure rates of growth, and to be responsible for watering and fertilizing.

You might also consider having live animals such as fish, small reptiles, or mice. They are worthy of close observation and can be placed under supervised child care. It is important to check school policy before arranging for the presence of live animals in the classroom. Some jurisdictions allow for this with certain limitations and others maintain a ban on the presence of animals in classrooms. It is advisable to check with parents to see if any child has the potential for allergic reaction to the presence of fur or feathers. Certainly, the presence of animals allows children to observe and practice the correct housing and handling techniques; it promotes responsibility. However, it does raise the issue of safe handling, safety for the child, and precautions to maintain levels of sanitation/health (Taylor, 1993).

Practical tasks may be constructed in such a way that some activities take place in the hallway or even outside the building. This raises the issue of safety and adequate supervision. The teacher is responsible for ensuring that children beyond the classroom are under sufficient supervision. These activities might involve older students working in a "buddy" system, but remember older students cannot be given supervisory responsibility. Before activating investigations beyond the classroom, plan ahead to ensure a successful experience; be sure to check local policy regarding supervision and transportation of children and the legal responsibilities of the teacher (Taylor, 1993).

The materials and equipment at activity-based learning may require that funds be raised beyond those available by annual grant to the school. You could take on the responsibility for this individually, but it is more efficient and enjoyable to do this as a joint effort with colleagues.

Before embarking on a fundraising effort be sure to have this approved by administration. There may be specific policies at the school or district level that govern when and how these are conducted. Although parents and various types of parent organizations are likely sources of funds, it is worthwhile to widen the potential donor pool. In some areas local community groups have "adopted" schools and taken over fundraising functions. Displaying the results of learning through science and mathematics centers, holding a science fair or academic olympics, or conducting science or mathematics update nights for adults in the community can serve to enlarge the donor pool. Some literature focuses on the value of contacting and informing both the parents and the community at large. These people can serve to be a potent political force if they see definite learning advantages through activity-based learning (Leavitt, 1993; Orenstein, 1992).

For Starters...

1. Gauge support of fellow teachers and administration for activity oriented child learning.
2. Determine how well your classroom is situated for a variety of child activities.
3. Check local policy regarding the presence of live animals in the classroom.
4. Check and follow local policy regarding fund-raising activities.
5. Establish an accounting system for funds and always work with a partner teacher and ensure the fund account is independently audited once per term.

Class Configuration

When using science and mathematics activities to introduce more child-centered learning, the composition of the class will also affect the way in which the tasks are introduced and utilized. Class size and its composition may determine where work areas can be situated in the room, how they may operate, and the optimum number of children at each location (Lamb, 1991; Leavitt, 1993). One serious consideration is to work in partnership with another teacher or form a "buddy" system in which older students become mentors for the younger children.

Another advantage of this option is to place work areas both in classrooms and possibly in the adjoining hallway, at least on a temporary basis. This option allows primary children to meet older students and also exposes them to other adults in the building thus reducing their dependency on the individual classroom teacher. Such combinations when used with appropriate frequency can achieve goals in both the objective and affective domains (Leavitt, 1993).

Your class may be composed of students with a range of ages (multi-age grouping by design) and it will certainly have a broad range of individual abilities. These factors bring their own set of expectations on the part of school and parents (Institute on Education Reform, 1994). The teacher's role is to know each child well enough to select group combinations that match children's strengths with their areas of weakness to the mutual benefit of all. This is no easy task; it requires constant monitoring and assessment of child progress and interactions.

Group composition will change for a variety of reasons, some academic and some social. All children have something to offer every group and it is the teacher's role to recognize this and use it accordingly (Institute on Education Reform, 1994). The class may be fully integrated and have children who present significant personal challenges. These may be physical, sociological, or psychological. Group selection should reflect the intended tasks and children's needs; groups consisting of one through four children are suggested, but ensure each member will be actively involved.

Limits to Available Resources

Resources come in various forms. Some you may influence quite easily, yet others are improved through the long term with support from other people. This section considers people as a vital school resource; the school library or resource center; and the different materials and equipment that are required to make a successful science-mathematics program for primary children.

Human

Structuring learning through science and mathematics practical investigations is a challenge for any teacher. It may represent a different approach to teaching; it probably challenges your experience and stretches your knowledge base more than in the past. If there are concerns in this regard you might look to a teaching colleague who has some experience in this area. Another positive step is to identify professional development opportunities that are provided through your district, state, or province that focus on teaching strategies for an activity-oriented classroom. Don't be afraid to take the initiative and inquire about these possibilities. If they don't exist currently, your school might lead the movement to begin this line of professional development.

Supervisory staff always prefer to respond to a need identified at the school level rather than to impose one from outside. Good examples are to be found in the literature that describe the move to authentic learning and assessment, constructivist classrooms, child-centered learning, and the importance of school based professional development (Brookes & Brookes, 1994; Institute on Education Reform, 1994; Whitby, 1993).

If you are concerned about your knowledge base in science and mathematics, don't let this deter you from using child-centered practical investigations. It is quite likely that student research and questions will take you into areas with which you are unfamiliar. That is fine; children and parents cannot expect you to be the font of all knowledge. In fact, it is better to create a model in which you assist the process of children discovering relevant information through research. In this "information age" it is very important that children develop this skill; making wise research decisions is becoming as important as accumulating factual information on a variety of topics.

There may be sources of information within your school, but also relatives and friends can form a network in which information and expertise are shared. Additionally, parents of children may work in a particular field of interest and become resource people (Galen, 1992; Herrick & Epstein, 1991; Jewett, 1992). Assess your community for alternative information resources. As more people "work from home" there are likely to be technicians, scientists, and engineers who would be pleased to share their experience of science/mathematics with teachers and children. Community minded people may offer to visit your class or be interviewed by children (Derrington, 1993). Richer learning experiences are created by having children directly involved in the process of investigation rather than the teacher acting as the go-between.

Your school, state or provincial government agencies, and professional associations may offer a "dial-an-expert" service where you are able to leave a specific question through a voice mail clearinghouse system and then subsequently receive a reply from the appropriate expert. Many Canadian schools will have access to the "Innovators in the Schools" program. Similar systems are becoming available through e-mail; these offer you the ability to print the response for student use.

One valuable informational resource available through electronic mail is the AskERIC service provided by the Educational Resources Information Center (ERIC) supported by the U.S. Department of Education. Anyone can send a question to askeric@ericir.syr.edu and receive a response within 48 hours. The AskERIC service also maintains a virtual library of information on the World Wide Web at http://ericir.syr.edu.

With increasing numbers of companies and organizations creating "home pages" on the World Wide Web, it also becomes easier for teachers and children to make direct contact with a company and seek information. At the risk of downgrading the importance of regular written communication, e-mail provides a much faster response time, and this is good for short term assignments. If your school is not connected to the Internet system, or staff has little Internet experience, there is yet another professional development opportunity for you and your colleagues. Providing Internet access in the school adds one more dimension to the research "tool-kit" available to teachers and children. Even though the Internet will not replace other modes of research, it has a role to play in the lives of primary age children now, and will become even more significant throughout their schooling.

For Starters...

1. Look for professional development opportunities that promote strategies where children learn through practical activities.
2. Begin developing a network of contacts who can exchange knowledge in science and mathematics.

Learning Resource Center

Science and mathematics centers in the classroom go beyond simply placing a group of children at a location to work on an assignment from "the text." It has a physical structure that allows presentation of information in a variety of forms, it will provide instructions and set practical assignments. More importantly, it will encourage open-ended investigation (Raines & Canady, 1992; Raines, 1994). This means that a variety of resources must be provided or be easily available to children.

It is important to assess the age appropriate holdings of the school library or resource center. One early task is to consider the current role played by the library and if it might become a multi-task center that extends beyond print holdings to offer audio-visual materials, manipulatives, and equipment.

Through the school resource center, a variety of information sources can be stored and accessed. Seek answers to these questions: Does the district/state/province provide loan service for videos and computer software? What is the loan period for classroom use? Do rights to copy videos or software exist through such agencies? The school resource center might become the avenue through which these resources pass.

Science Equipment and Materials

The prescribed curriculum will suggest some ideas for practical activities. It will also indicate the type of equipment and materials needed for your class. Be cautious when using equipment lists provided with commercial texts or those designed by a supply company in cooperation with a publisher. Generally, these over-estimate what you require, or they assume that ten groups in the class will be doing the same activity simultaneously. Buying premeasured quantities of acetic acid, sucrose, and sodium chloride will definitely be far more expensive than buying vinegar, sugar, and table salt at the local grocery store. Buying prepackaged material kits for specific programs is a very expensive way of purchasing some ordinary items. Investing time by reviewing the materials list and identifying local sources will probably save many dollars. Check local policies regarding purchases. Properly documented and audited local purchases are a good option.

To ensure the required equipment is in the building and available when needed, it is important to conduct a school-wide inventory. Depending upon the philosophy of the principal and staff, there may be very open sharing of resources, but some people may have their own "territories" and be reluctant to share with others. Developing a single resource center for the school may alleviate the frustrations of those with "territorial tendencies," and shifts the emphasis to a team effort eliminating a "mine and yours" stance. A full school inventory in an older building may uncover a "gold mine" of equipment that has been stored so well, for so long, that current staff do not know of its existence!

It might be that you have not used a piece of equipment before and are not sure about its correct operation. In this case find the supplier and call its help line, talk with a district science or mathematics support staff member, or find a teacher at a local junior or senior high school who knows this equipment. Any of these people should be happy to offer help. In such cases, clarify the situation. You don't want to misuse the equipment, compromise safety, and instruct children incorrectly (Gough & Griffiths, 1994; Taylor, 1993).

As more practical activities are developed, you will better assess how much equipment and expendable materials will be needed to supply them. Some teacher resource materials that accompany commercial programs give very practical suggestions on quantities and provision of materials and tools (e.g., Harcourt Brace; Addison-Wesley). It is better for children to have reasonable access to these and use them in a responsible manner than for the teacher to continuously play the role of supply person. Whether you run total class exercises or use various learning centers, expendable materials will be consumed, and likely at a faster rate than you originally estimated!

In the primary classroom many materials come from the "household" category. However, it is very important that children be instructed in the safe handling and storage of these chemicals. It is never too early to develop safe procedures regardless of the substance. Powders (baking soda, flour), granulated solids (sugar, fine sand), and liquids (vinegar) are all fairly low risk, but teach children safe handling techniques.

Remember to be cautious about children who may have allergies to certain foods, odors, and different materials. These cautions are not meant to scare neophytes away from practical activities or using centers, but are to emphasize the importance of good planning and advance contact with parents. Plan well and be able to solve little challenges on the fly (Gough & Griffiths, 1994, p. 168; Taylor, 1993, p. 4).

For Starters...

1. Find the current curriculum guide and establish the expected student learning outcomes.
2. Inventory the school for the equipment required to support the program.
3. Make a list of companies that are able to supply equipment. Get telephone and fax numbers, and order their latest catalogue.
4. Check the local policy regarding purchases that use a capital budget and the policy for purchasing small scale consumable items.
5. Research and follow the local guidelines regarding the use of chemicals, materials, and tools in the classroom. Clarify any areas that are vague.

Overcoming Limitations: A Starting Point

Although mentioned in other sections of the chapter, we believe these four strategies offer teachers a starting point for dealing with the challenges of using activities, projects and learning centers.

1. Exploratory activities prior to teaching science and mathematics concepts or units can provide information about children's prior conceptions, including those based

on cultural beliefs and their own experiences, which could be in conflict with scientists' ideas, models, and theories. Exploratory activities can also provide insight about children's vocabulary and the meanings they associate with specific terms.

Exploratory activities are not teaching activities. In fact, children might view them as games. The idea is to find strategies that prompt discussion, e.g., slides, demonstrations, card sorting, and pictures. Discussions can vary from whole class to groups to individual. With the information provided from these activities, projects and learning centers can be adapted to include a range of teaching activities that appeal to and match the learning needs of the children.

2. Creating learner profiles for each child might also be helpful. A series of activities matching each learner's preferred learning style, e.g., kind of structure each learner is most comfortable with, preferred learning modalities, and areas of intelligence, can be identified. From this information teachers and resource persons can develop an individualized education plan that fits the needs of the learner and the preferred teaching approach of the teacher.
3. Identify specifically the concepts, skills, and vocabulary you expect children to understand as a result of the activities and learning opportunities you provide. Next determine what is expected or hoped for as a level of understanding of the concepts, vocabulary, and ideas before beginning the unit. Knowing what is expected while planning the activity series, projects, and learning centers is the best way to track the opportunities we provide each learner. In addition, we can monitor understanding and areas of difficulty.
4. Assessment activities and methods should also be determined while planning the unit. Before teaching a unit, assessment activities can help identify areas where children's understandings conflict with or may be barriers to understanding science and mathematics. Within a unit, assessment activities can help in monitoring understandings. Each learner's success should be determined by a combination of activities that check for expected understandings and those which allow children to tell us things they learned we did not think to ask or explore. An evaluation is a combination of our expectations and learners' accomplishments.

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Section 2

Activity Series

This section begins with "Activity Series and Activity Centers: Paths to Learning." Peter Rillero explains the need to make science and mathematics a regular part of early childhood education and explains how activity series and centers can facilitate this goal. He presents approaches for enhancing learning using these methods. Chapter 4 serves as an overview for this section as well as Section 3: Activity Centers.

In Chapter 5, "Learning Cycles and Simple Machines: Wonderful Ideas and Powerful Data," Susan L. Westbrook, Laura N. Rogers, and Jack Wheatley describe constructivist principles, experience-based learning, and the learning cycle, They present an activity series using the learning cycle to teach concepts of simple machines, specifically pulleys, levers, and inclined planes.

Barbara Foulks Boyd, Carolyn Butcher Dickman, and Meta Van Sickle discuss constructivism and their 5 Es paradigm for learning (engagement, exploration, explication, elaboration, and evaluation) in Chapter 6. They present activity series that use this approach and teach ideas related to weather. Their unit of weather contains the following sections: wind, temperature, the water cycle, and weather trends.

Chapter 7 is a collaborative contribution made by Michael J. Smith, Betty A. Wier, Betty-Jane Cain, Karen Fredricks, and Sharon Wilson. They describe their work designing an activity series on rocks developed from national and local standards. The results of a pre-assessment changed some of their initial ideas and led to the development of the Special Rocks activity series. The writing team details this 11-day activity series and provide individual reflections on the process and product of their work.

Nancy R. Lebofsky and Larry A. Lebofsky present in Chapter 8, "Stars and Constellations in the Classroom," a classroom tested activity series for integrating astronomical concepts into early childhood mathematics, reading, language arts, social studies, and fine arts instruction. Their activity series explore the size, shape, and color of stars; life cycles of stars; constellations; literature connections; and skylore projects.

Gerald Wm. Foster, in Chapter 9, "The Mathematics and Science of Seeds," describes how to use seeds to teach important mathematics and science skills. The series includes the following activities: Classification and Ordering, Counting Seeds in Containers, Volume of Discontinuous Solid Objects, Balancing and Weighing Seeds, Seed Art and Geometry, Nonstandard Linear Measurement, and Planting and Germinating Seeds.

The final chapter in this section is written by James J. Watters and Carmel M. Diezmann. They discuss ways children are gifted, needs of gifted children, methods of teaching gifted children, and relationships between science and mathematics. They advocate programs that feature expanding experiences, cognitive apprenticeship, cooperative groups, positive social environments, affective development, and knowledge creation. They present a program with these features and describe activity series that are appropriate for all students. The 10-week program includes the following series: Week 1: Space Travel, Week 2: Travel, Week 3: Sound, Week 4: Animals, Week 5: The Forest, Week 6: The Night Sky, Weeks 7 and 8: Pet Paradise, and Weeks 9 and 10: Movement.

Chapter 4

Activity Series and Activity Centers: Paths to Learning

Peter Rillero

They put the last wire on the battery terminal—the light bulb shines and the delicate strand of steel wool glows red hot. Her normally tranquil partner exclaims, "Its red...its melting!" The steel wool snaps and the ends curl from the break point like hair pulled from a curling iron. A silent moment passes; bright eyes focus on the manipulatives arranged on their table. Her partner says it just as Angelica realizes, "The light went out!"

Ms. Williams senses the excitement and walks over. The teacher speaks no words but her body posture shouts her interest. The children rush to describe what happened, like two painters alternating strokes on a canvas, they paint a picture of their experience. "How interesting! I wonder *why* the bulb went out," ponders Ms. Williams. Angelica starts to explain and in the process of formulating her thoughts it fully hits her, the electricity needs a full path to make the bulb glow.

In that moment, an activity became a learning event. Events form the mosaic of life. In infancy a child learns about security and contentment through the familiar events of a mother's care. Teenagers engage in animated conversations about events experienced. Older adults take time recalling the events of life—some enjoyed, others endured, but all contributing tiles in the mosaic of life.

Since events form the mosaic of life, education based on "events" provides a strong foundation for learning. The benefits of "event-full" teaching, or active experiences, in early science and mathematics education are well documented. Event-full science and mathematics instruction has been shown to increase content learning and achievement (Bredderman, 1982; Mattheis & Nakayama, 1988; Saunders & Shepardson, 1984). Not only do activity-based curricula improve learning in science and mathematics, but their use is also correlated with greater creativity, language learning, and improvement in early literacy (Bredderman, 1982; Huff, 1971; Morgan, Rachelson, & Lloyd, 1977; Neuman, 1981; Quinn & Kessler, 1976; Rodriguez & Bethel, 1983; Willman, 1978).

The realized benefits of active, hands-on learning have resulted in moving past the question of "should activity learning be used" to questions pertaining to optimizing the approach. How are activities best used in the preK-3 curriculum? How can activities produce a scaffolding of learning? What types of activities should be used? What are teacher roles in the process? In this chapter I discuss answers to these questions, and explain the rationale and methods of activity series and activity centers.

Important But Not Special

Scientific and mathematic experiences should be normal events in children's lives. They induce children to examine and think about the world. Children's insatiable quest to understand their environments make them receptive to active experiences in science and mathematics. While these subjects are important, they should not have a distinguished designation. The importance of experiences in science and mathematics demands they be a regular part of early childhood experiences—all curricula should include regular episodes of studying the world and opportunities for higher level thinking.

Small regular doses of science and mathematics are better than neglect with occasional binges. Consider the following two situations involving environmental activities, both using six hours of classroom time. In one situation, a block of six hours in one day is devoted to environmental activities. In another situation, activities of approximately forty minutes each are implemented three times a week for three weeks. To be sure, the one day of extended focus may help young learners get excited about the environment; but moving from one activity immediately to the next may not allow children time to adequately reflect on what they have done. With activities sequenced over several days, children have time to think about their experiences between activities. They can reflect on the way home and at home. They can discuss activities with their parents, siblings, or friends. They have ample time to formulate questions to think about or to ask. The spacing between activities gives time for thought; the regularity of activities keeps children's attention over a longer period. In short, an extended series of activities is usually superior to a full-day block of activities because it provides opportunities for reflection and time for children to grow with what they have learned. Assiduous events provide a focus over time. Constructing understanding, such as unitizing—the assignment of a unit of measure to a quantity—"develops over time and with experience in varied contexts" (Lamon, 1996, p. 188). Children visit and revisit concepts, allowing them to construct deeper understanding.

Unassiduous science and mathematics instruction consists of one-shot activities with limited opportunity for conceptual growth. One month children may do an activity with plants; the next month they get a short experience with magnets. Children may participate in the activity, but forget the "what" or "why" of their actions. Discontinuous experiences offer limited opportunity for children to connect concepts. Science and mathematics experiences in the early grades should be concrete and regular, with an emphasis placed on children making connections across concepts and learning experiences.

Activity Series and Activity Centers

Active experiences in science and mathematics should be a normal part of children's lives. Activity series and activity centers provide frameworks for making such experiences a regular part of early childhood school experiences. My definition of an activity series is: *A sequence of dynamic events for promoting conceptual development.* Learning is achieved through active experiences; events in a series are linked; and the experiences occur with some regularity.

Activity centers are discrete areas in a learning environment where learners investigate aspects of the world in a more self-directed manner. Both activity series and centers place an emphasis on active learning experiences. In activity series students work individually or in small groups, but usually the entire class is working on the same activity. Activity centers allow students to work with greater autonomy—students can experience the centers in their free time and work at their own pace. Activity centers contain sets of activities for enhancing learning, thus activity centers are a subset of activity series. The remaining portions of this chapter apply to both activity series and activity centers; in Sections Two and Three of this book, authors present detailed examples of activity series and activity centers, respectively.

Activities in series and centers are linked, and the linkages may take a variety of forms, including a systems, thematic, or process skills approach. In a systems approach the parts of a whole are studied. Examples include investigations of pendulums, puddles, or objects in the sky. A thematic approach links events through a theme. Examples of themes are patterns, equilibrium, or adaptations. A third method of linking events is a skills approach. In this approach certain mathematics or science process skills are chosen as the focus. For example, a collection of activities may focus on early counting strategies, estimation strategies, measurement tools, or classification skills. The linking of activities is important; it helps children build upon their knowledge and skills–through this scaffolding they develop deeper understandings.

Constructing Understanding

A young child's understanding of the world comes almost exclusively from his or her experiences with the world; these experiences form a series of ongoing events (Nelson, 1986). Activity series and centers provide ongoing school-based events assisting children in combining past and present experiences into an understanding of the world. Experiences with the world incite interest and provide a concrete base for abstract thinking.

Activity series are flexible, they are not fixed strings of predetermined activities. The events used in the series must come from a consideration of children, their interests, abilities, and prior experiences. As the National Council of Teachers of Mathematics Standards state, "It is clear that children's intellectual, social, and emotional development should guide the kind of mathematical experiences they should have in light of the overall goals for learning mathematics" (1989, p. 18). So, a series flows in a logical manner, but not a rigid manner; different students and classes will benefit from different activities. Published activity series, such as those presented in the next two sections, present possible frameworks for educational experiences. However, the actual experiences will depend on students, teachers, and classroom circumstances.

Activity series focus on conceptual development and they require children to think about what they are doing. They feature active learning experiences, which should not be misconstrued as "do this, then do this, then do this" or as education of the hand. Effective activity series do emphasize action, but not in a mindless way. Events in the series induce thought. Experiences—followed with thought about the events—facilitates the formation of connections between concepts. The doing *and* the reflecting allow children to construct understanding and is an integral component of constructivist classrooms. "Constructivism implies that students require opportunities to experience what they are to learn in a direct way and time to think and make sense of what they are learning" (Tobin, 1990, pp. 404-405).

Negotiating Meaning

A vital component of effective activity series is discussion. It helps build linkages between activities and assists children in building connections between concepts. When children have the opportunity to talk with each other, they are motivated to formulate and compare their ideas.

Vygotsky's Zone of Proximal Development, "*the distance between the actual developmental level* [of the child] *as determined by independent problem solving and the potential development as determined through problem solving under adult guidance or in collaboration with more capable peers*" (Vygotsky, 1979, p. 86), provides an important rationale for teacher-student and student-student dialogue. "Learning takes place as theoretical/scientific concepts ascend from the abstract to the concrete in the zone of proximal development (z. p. d.), in interaction with more knowledgeable others" (Lerman, 1996, p. 138).

To communicate ideas, children focus, reflect, and organize their thoughts. This facilitates the conversion of a child's implicit knowledge into explicit knowledge (Nelson, 1986). Most of us have experienced this phenomenon; we understand a concept better after we have explained it to someone else. A question, from a teacher or a student, can be an effective catalyst in the conversion of a child's implicit knowledge into explicit knowledge.

Children will view events from different and unique perspectives. The sharing of ideas guides the learner into thought from a variety of mental views. When children compare and discuss their views they negotiate meaning; children are developing shared conceptions about the world.

Less is more

Activity series and centers focus on a small number of important concepts. Depth of understanding is more important than breadth of coverage. A topic isn't "covered" in one day and then moved away from; rather, a topic is approached through connected experiences over several weeks. This provides the child with numerous opportunities to think and talk about what they have been doing in school. Reflection over time is thus encouraged, promoting an incubation of ideas. Children have the time to ponder the ideas they gain from these related events. In doing so, the physical maturing of their minds—as they seek to understand concepts—may synergise cerebral and conceptual development.

Active Teachers

Teachers play critical roles in all aspects of activity series and centers. Teachers identify goals of the science and mathematics programs, choose activity sequences to achieve these goals, create opportunities for reflection and discussion, and guide children's conceptual development throughout the activities.

Getting Ready: Pre-instruction

Any effective science or mathematics program has a vision of what students should learn. The vision develops from knowledge of children, the teaching environment, and the world. With a vision short term goals or objectives can be identified. Using activity series or centers that do not meet a program's objectives, or using them when no objectives have been identified, makes the activities seem irrelevant and hollow. Thus, activity series and centers should help achieve specific instructional goals.

The best topics for activity series are those that naturally facilitate the use of concrete hands-on experiences. The *National Standards for Science Education* state:

> During their early years, children's natural curiosity leads them to explore the world by observing and manipulating common objects and materials in their environment. Children compare, describe, and sort as they begin to form explanations of the world. Developing a subject-matter knowledge base to explain and predict the world requires many experiences over a long period. (National Research Council, 1996, p. 123)

Some topics translate easier into concrete experiences. For example, the topic, "plant growth," is easy to translate into active student learning experiences. Some topics are more abstract, but can be made more concrete through sensory experiences. Mathematical manipulatives make multiplying, dividing, and understanding fractions more concrete and their use provides a foundation for more abstract thinking. Two chapters in this section of the book show how the solar system, an abstract concept for young children, can be made more concrete through hands-on experiences.

When the objectives and topics of a curriculum are clear, the choice of activities is made easier. Activities should be chosen or developed with an appropriate level of difficulty for the children. Areas of concern about the level of difficulty include manipulation of materials, safety, children's ability to understand concepts presented, and reading or writing requirements (Rillero, Brownstein, & Price, 1994).

Resources are also an area of concern for teachers. Lack of resources limits many teachers from using manipulatives in science and mathematics instruction. To be sure, no school has all the materials, resources, and equipment to do even a small fraction of the published science or mathematics activities. Yet, the classroom, school, and school grounds contain enough materials for an infinite number of activities. In fact, simple everyday materials can be the most effective materials for helping children learn about their world.

Guiding Learning

The goals of the program are identified and objectives determined. Activity series and centers are chosen to complement the interests and abilities of the children and to achieve the objectives of the program. Now children and teachers embark on their shared sojourn of discovery.

Teachers act as guides on paths of learning. They help create and optimize experiences. Along the path teachers provide motivation, opportunities for reflection, and feedback for the children. The use of activity centers makes it possible for different children to explore different paths—the path may be more individualized but still a guide enhances learning. In sum, the paths to active learning require active teachers.

When we embark on a journey, we often want to know where and why we are going. Teachers need to set the stage for activity series and centers and perhaps introduce individual activities. The stage setting need not tell children what they will discover, but it should provide a context for the learning. Introductions to series and centers should inspire the children. Motivated children are more engaged as they experience the events. Captivated engagement improves learning and reduces classroom management problems.

During the journey, teachers need to observe and talk to the children. Are they motivated and excited as they explore concepts? Or, are they frustrated and becoming unruly? What areas challenge the children? Which areas of difficulty should be addressed with more activities or discussion? This information helps determine how the activity series will unfold.

More than helping teachers learn about children's conceptions, discussion helps children build deeper understandings. Discussions promote reflection about activities and the patterns in the events. Learners connect concepts in their minds when they formulate thoughts and when they listen and evaluate the thoughts of their peers. "Activity based classes can have marginal results where there are few opportunities to share ideas" (Flick, 1993, p. 4). Discussion makes event-full learning more meaningful.

Discussion can occur in a variety of contexts within the classroom. It can occur between children or between a teacher and one or more children. It can occur in dyads, small groups, or whole classes. Exciting events will precipitate many discussions, and effective teaching capitalizes on the "discussible moments."

Teachers can induce reflection and discussion through the establishment of a positive classroom atmosphere and through the use of provocative statements and questions. A good student discussion not only produces student talk, but gets other children to listen and respond to the student talk. "When students compare their ideas, they frequently modify, consolidate, or strengthen an original argument or reject an initial attempt in favor of another that appears more sensible" (Maher & Martino, 1996, p. 196). In a collaborative study, Cobb (1995) reports on the success of a second grade teacher in creating a climate conducive to discussion.

> The social norms established by most of the groups with the teacher's guidance included explaining one's mathematical thinking to the partner; listening to, and attempting to make sense of, the partner's explanations; challenging

> explanations that did not seem reasonable; justifying interpretations and solutions in response to the partner's challenges; and agreeing on an answer and, ideally, a solution method. (Cobb, 1995, p. 365)

Maher and Martino (1996) describe 6-year-old Stephanie and three boys working on a story problem. Stephanie says, "Wait a second, Buddy, you can't just say six! Wait...I think we should read this word. Wait for us, Buddy! Remember, you can't just jump to conclusions like 'I know this'" (Maher & Martino, 1996, p. 194). The quote reveals the powerful learning situations when students listen to each other, compare ideas, and challenge each other to think at higher levels.

Teachers should encourage student thinking and not just the arrival at the correct answer. For example in mathematical problem solving, "questions related to economy may encourage more sophisticated strategies" (Lamon, 1996, p. 191). Queries such as, "Can you think of a better way to do that?" and "Can you think of a quicker way?" can help children develop advanced strategies.

Seeking first to understand student ideas, and then helping children scaffold concepts, are important components of teacher-student talk to promote conceptual development (Fleer, 1992). Discussion helps teachers understand children's conceptions. When teachers understand children's conceptions they can more effectively ask questions or make statements that help children build on their ideas (Maher & Martino, 1996). The discussion not only helps children build their conceptions, but sets the stage for the next activity, making discussions as much as a closing as a beginning.

Conclusion

Events are the tiles in the mosaic of life; event-full learning should be the basis of education. Activity series—sequences of dynamic events for promoting conceptual development—and activity centers—autonomous regions of a classroom where children investigate aspects of the world—provide connected and recurrent event-full learning experiences.

Whether learning how to play the piano, developing proportional reasoning, or investigating the world, short-term regular active learning experiences are best for promoting understanding and building skills. Activity series make science and mathematics instruction more powerful and more enjoyable. With frequent and connected science and mathematics hands-on experiences, scientific and mathematical thought becomes habitual and grounded in concrete experiences.

One of the greatest forces in a young child's life is the drive to understand their world. Activity series and centers provide an additional channel for this drive. In well-designed series and centers, children's quest to make sense of aspects of the world is rewarded with understanding. Far from being satiated, this rewarded thirst for understanding intensifies. One of the greatest experiences in teaching is witnessing a child's flame of curiosity combust with a higher intensity.

About the Author

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Chapter 5

Learning Cycles and Simple Machines: Wonderful Ideas and Powerful Data

Susan L. Westbrook, Laura N. Rogers, & Jack Wheatley

The recently published *National Science Education Standards* (National Research Council (NRC, 1995) encourages the use of inquiry in science classrooms at all grade levels. Why would a teacher strive to make inquiry the mainstay method in an elementary school science classroom? The significance of such an effort was eloquently stated by Eleanor Duckworth (1987) as she related her interactions with a boy named Kevin who constructed his own solution to a serial order problem during an interview:

> The having of wonderful ideas is what I consider to be the essence of intellectual development. And I consider it the essence of pedagogy to give Kevin the occasion to have his wonderful ideas and to let himself feel good about having them. (p. 1)

What would it take to provide not only "occasions" (experiences) for students to have "wonderful ideas," but to also create a classroom environment that encourages student ownership of those ideas? Perhaps the roles of students and teachers would center around student conceptions. Students might be in charge of collecting and analyzing data, making sense of results in light of questions, and finding connections with other ideas as they further investigate newly-invented concepts. In such a classroom the teacher might serve primarily to provide materials and resources, time to explore, and opportunities for students to share findings. Recognizing that not all students learn the same thing at the same time in the same way, the teacher would make allowances for a wide range of intellectual and conceptual development. In essence, students would engage directly in the process of scientific investigation.

The purpose of this chapter is to examine how teachers can facilitate student thinking through the use of scientific investigation. The *learning cycle* is used to illustrate an instructional method that can be used to facilitate the having of "wonderful ideas" among students. Considerations regarding the theoretical foundations of the learning cycle will also be discussed. The chapter concludes with a detailed look at the practical aspects of using the learning cycle to teach about simple machines in a third grade classroom.

Theoretical Considerations

A number of research studies during the past decade have focused on how students learn. Bodner summarized this process and its implication for teaching in this way:

> There is no conduit from one brain to another. All teachers can do is disturb the environment. Effective instruction depends on our ability to understand how students make sense of our "disturbances" (stimuli) rather than how we make sense of those stimuli ourselves. Knowledge is constructed by the learner. (Hackett, 1992, p. 1)

Cognitive development in children takes place in minute steps over time as they interact with the environment (Miller, 1993). Piaget (1975) recognized this relationship between the environment and the learner as cognitive adaptation and considered it an invariant in the cognitive development of the child. Many authors (Good & Brophy, 1994; Matthews, 1992; O'Loughlin, 1992; Scott, Dyson, & Gater, 1987) have provided support for this notion of personal construction over time. The implication of this for teachers is pointed out by Wheatley (1991); teachers cannot give knowledge, they can only provide experiences. A general view of science learning from a constructivist perspective can be summarized as follows (Driver & Bell, 1986; Loucks-Horsley et al., 1990):

1. Learners bring their own understandings and experiences (prior knowledge) to a science lesson. Where there is more diversity in the student population, there will be a greater variety in students' understandings of the concepts being taught. The teacher can "level the playing field" by allowing students to discuss their various understandings and by providing common experiences for all the students.
2. Learning is the construction of meaning by the learner. When learners have the opportunity to manipulate materials to test their understandings and ideas, they may change or affirm their own understandings.
3. Meanings constructed by learners may not be those intended. Teachers can assist students by providing an environment in which learners can make sense of their experiences through experimentation, analysis, and dialogue.
4. Construction of meaning is a continuous, active process and is the responsibility of the learner. Teachers must rethink their role in the learning process as we realize where the control for learning lies. Teachers cannot do "to" or "for" students if students are to be in charge of their constructions. Learning is an active process carried on by the student; the teacher can facilitate this process by providing an environment in which ideas can be explored and analyzed.
5. The end product of learning belongs to the learner. This product, this concept, is more than memorized bits of information. It is an understanding that is meaningful to the child. It is a meaning that the child has actively constructed from prior knowledge and has continuously adapted through additional experiences. It is the student's view of the world.

Although some researchers may renounce the necessity of experience-based learning for children in elementary grades (e.g., Metz, 1995), most science educators agree that doing science leads to greater understanding than hearing or reading about science. Support for experiential learning emerges from developmental perspectives on cognition as well as those with a physiological base. Work in brain research, for example, indicates that multimodal learning (i.e., vision, hearing, and touch) involves several regions of the brain and, thus, has the potential to increase brain activity. Anderson (1992) asserts that learning environments that provide for and foster multimodal input could "stabilize long-term representation of experience and facilitate recall" (p. 1043).

The learning cycle is used here to illustrate an instructional model based on constructivist principles. The learning cycle provides the classroom teacher with a sequential, well-researched model for teaching investigation-based science (Andrews, Huber, & Clark, 1994; Kyle, Bonnstetter, & Gadsden, 1988; Renner, et al., 1973; Schneider & Renner, 1980; Saunders & Shepardson, 1987; Westbrook & Rogers, 1994). Each learning cycle focuses on a target concept and a group of related ideas. The format of the learning cycle—exploration, invention, expansion—also involves the students in a variety of learning modes and opportunities.

The late Dr. Robert Karplus is credited with the initial development of the learning cycle method in the 1960s (Karplus & Their, 1967). Karplus began developing and teaching lessons for elementary and junior high students after speaking in his daughter's second grade classroom. These teaching efforts, followed by his analysis of science learning among students, led to discussions between Karplus and the French psychologist, Jean Piaget, and to the design of an elementary science curriculum paralleling the nature of science and the child's ways of knowing. That curriculum model, first published in 1967, consisted of three phases: exploration, invention, and discovery (now referred to as the expansion or the concept application). The learning cycle resembles what most of us know as the "scientific method." It also parallels the developmental psychology of Piaget (1953) who described the process of learning (assimilation, accommodation, and organization) and documented the need school-aged children have for concrete experiences.

Three different types of learning cycles have been proposed: descriptive, empirical-abductive, and hypothetico-deductive (Lawson, Abraham, & Renner, 1989). The degree of open-ended student exploration increases through the continuum of descriptive to hypothetico-deductive learning cycles. A further discussion of the learning cycle is beyond the scope of this chapter, but those interested could learn more by reading Lawson, Abraham, and Renner (1989), Renner and Marek (1988), and Lawson (1995).

The learning cycle has been a part of many science classrooms since the 1960s. The initial *Science Curriculum Improvement Study* (or *SCIS*) program (1970) was developed around the learning cycle model; teachers across the nation continue to implement *SCIS* curricula in their classrooms. Since that time other published curricula have taken on a learning cycle look. The recently published *Science for Life and Living* program from Biological Sciences Curriculum Study (1992) uses a modified five-stage learning cycle.

Practical Considerations: The Simple Machines Learning Cycle

What does a learning cycle "look like" as it is implemented in a science classroom? A learning cycle about simple machines is used here as an example of an investigation that generates data sufficient to assist student development of an understanding of the basic force/weight and force/distance relationships inherent in the concept of "simple machines." (We use the term "investigation" as a label for complex webs of continuous and interrelated activities.) This investigation would have been preceded by an investigation of force; students would have previously developed an operational definition for force (a push or a pull), and would be familiar with equipment used to measure forces. The investigation is presented in a step-by-step format to help interested teachers try out the learning cycle in their own classrooms.

Exploration Phase: Gathering Powerful Data

Students begin a learning cycle investigation by gathering data that will assist development of their understanding of a target concept. The form of the exploration may vary, but each student is given access to concrete materials. Manipulation of equipment and collection of data provide common experiences with the concept that will be helpful later during the invention discussion. "Hands-on" activity alone does not necessarily mean that students are collecting and considering data powerful enough to encourage knowledge constructions or reconstruction. The goal of the exploration phase of the learning cycle is to allow the students to engage in purposeful inquiries that produce powerful data. Powerful data may be defined as data that have the ability to disequilibrate the student, confront held alternate conceptions, or stimulate new conjectures about particular events. The ultimate goal of the exploration, then, is to provide a platform for meaningful student interactions with materials and classmates that will encourage further inquiry.

The context for the learning cycle about simple machines develops as students are shown an 80 pound sack of cement mix and asked to solve the following problem: "How can we get this 80 pound sack of cement mix from the classroom to the teacher's car and then into the trunk of the car?" This problem prompts students to consider what they know about moving heavy objects, provides a reason to know about how to move a heavy object, and serves as a pre-investigation assessment of their knowledge about simple machines. To help identify possible pathways to a solution, students are asked to draw their ideas about how the cement can be safety transported to the car and into the trunk. Once the drawings have been displayed and discussed, students are ready to pursue an exploration of forces and machines.

The exploration for our investigation of simple machines is fairly descriptive; particular data are collected for a particular endpoint. (A more open-ended inquiry follows in the expansion.) In order to invent the target concept, students need the opportunity to consider force and resistance in more than one simple machine system; our sample learning cycle uses pulleys, levers, and inclined planes (ramps). To provide the resistance and to keep extraneous variables to a minimum, the teacher could prepare objects of equal weight prior to the investigation or, better still, let the students produce the weighted objects themselves. One teacher cleaned small, empty coffee containers; filled them with 200 grams of sand; and wrapped them in brown paper (Students who produce their own "weights" may want to personalize them with color and drawings.) Once the objects are ready, students are asked to find the weights of the objects using spring scales. The data are recorded in a chart, either for the whole class or within a smaller group. Next, students are asked to find the force needed to lift the weight to a particular height (For instance, we use the height of the table or the seat of the student's chair.). Again, the data are recorded on the data charts. The teacher then introduces a simple pulley system (see Figure 5.1) and asks students to determine the amount of force needed to lift the weight to the height of the chair seat by using the pulley.[1] The data are

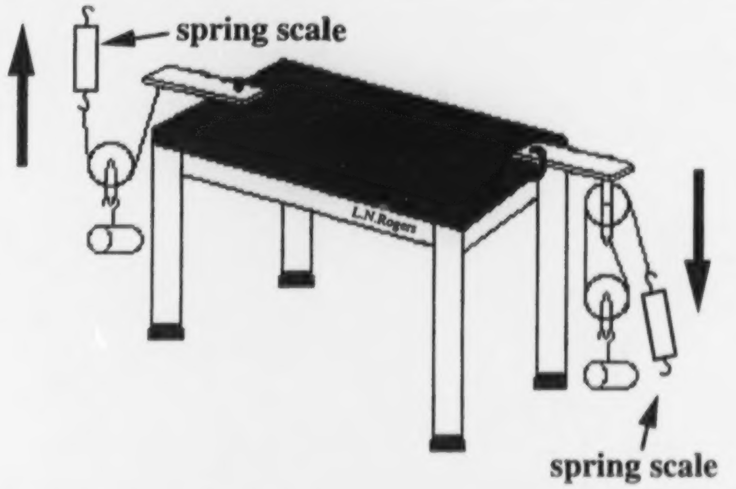

Figure 5.1 *Two ways to set up pulleys with a mechanical advantage of two.*

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[1] The type of pulley system used is not important, but the system should have a minimum mechanical advantage of two. Two ways to construct a pulley system with a mechanical advantage of two are given in Figure 5.1.

recorded on the data charts. The teacher leads a short discussion asking students to think about what patterns occur in the data and what the data mean. The goal of this brief discussion is to get ideas out in the "open" while the exploration activities are continuing. This also affords students with the opportunity to consider their thinking with that of classmates.

Next, students repeat their data collecting activities with a lever (fulcrum nearer the weight than the person—Figure 5.2) and a ramp (a piece of board about 1 meter in length propped up on the chair seat—Figure 5.3). The data are again recorded. Students now have several pieces of data to consider during the class discussion.

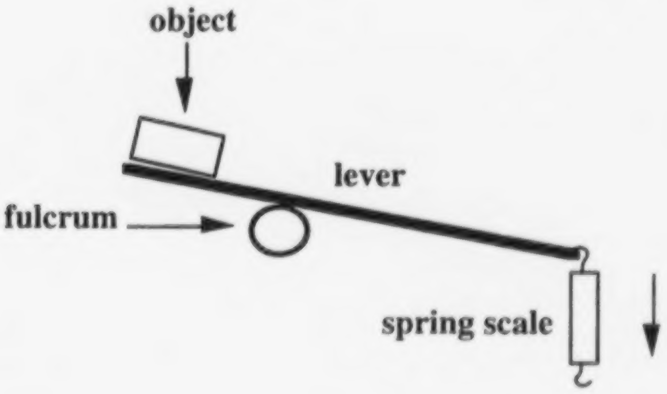

Figure 5.2 *Setup of a lever*

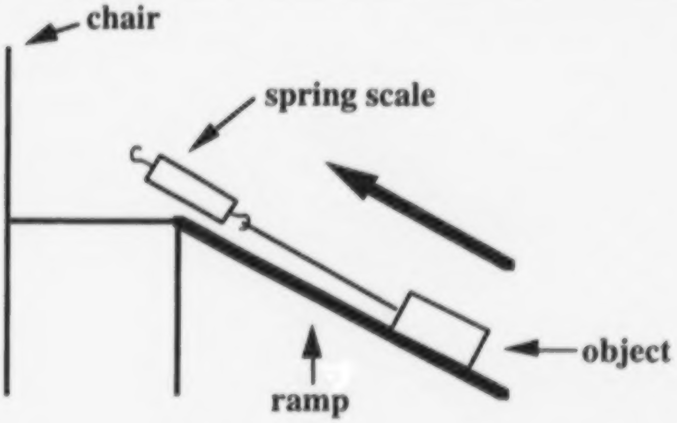

Figure 5.3 *Setup of a ramp*

When all the data have been collected, the teacher provides a class data chart (if not already available) to allow all the data collected by the class to be displayed and viewed. A sample chart for the pulley data is illustrated in Figure 5.4.

Group	Weight of Object	Force Needed Without Pulley	Force Needed With Pulley

Figure 5.4 *Class data chart for pulley investigations*

Conceptual Invention Phase: Making Sense of the Data

Next, a whole class discussion, called the *conceptual invention*[2], follows the exploration. The purpose of the conceptual invention discussion is to provide a forum for examining the data collected, having discussions about the meanings of those data, and summarizing and labeling the concept being investigated. All the data collected during the exploration are made available to all the members of the class by way of presentation on the chalk board, the overhead screen, a computer disk, or any other means by which the entire class can access the data of all the lab groups. A chart form such as the one we suggested in the previous section can be placed on an overhead transparency and used for several class periods. Large charts made from newsprint or butcher paper can also be posted and observed throughout a learning cycle investigation. For teachers and students who choose to use computer technology, the data can be entered by the students into a spreadsheet program and then made available via copy to all the students in the class. The spreadsheet method also allows the students to immediately construct different graphical representations of their data sets. Discussion about the data ends when the students have made sense of the information they gathered and have negotiated a common summary of their experiences.

In the case of the learning cycle about simple machines, the negotiated concept summary would be similar to the following statement: A simple machine is something that allows us to use less force to lift or move an object. Elementary science textbooks often assert that simple machines make our work easier or that we do less work when we use a simple machine. These devices do, in fact, make our work easier, but we still do the same amount of work and invest the same amount of energy; either a large force is expended over a short distance, or a small force is expended over a longer distance. Issues related to the concepts of work and energy, however, are not appropriate for students at this level. Keeping the concept to a simple statement about force differences will prevent setting up a misconception for later science classes.

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[2] We do not use Lawson, Abraham, and Renner's (1989) term "introduction." We use the earlier designation (invention) for the second phase of the learning cycle because we believe it more accurately describes the purpose of that phase.

Discussions can be utilized to engage students in the work of concept development. Teachers often move from activity to activity without allowing opportunities for arguments, pattern-finding, and knowledge construction. Our understanding of the learning cycle differs somewhat from some authors who write materials for elementary school science teachers. Term introduction and vocabulary drill are not, from our perspective, the focus for the invention discussion. When teachers view the second phase of the learning cycle as the "place where the vocabulary words are given," little or no discussion about the data occurs. We view the invention discussion as a student-oriented, data-driven process culminating in a concept summary generated by the students. Labels may then be applied by the teacher, if necessary. A successful invention discussion depends on the social negotiations and sense making that students engage in as they argue about patterns and variability within the data set and the viability of ideas proposed during those interactions.

Discussions in a learning cycle classroom typically modulate between small group and large group settings. During the exploration, students work in small groups to collect the data. The teacher may wish to place one or two focus questions on the board after the data have been collected and ask students to discuss their answers to the questions in small groups prior to the large group discussion during the invention phase. The large group discussion is characterized by its focus on data. In other words, the students and teacher are constantly reviewing and interpreting the data collected during the exploration phase. The teacher usually begins the discussion with a question, then allows the students to argue and negotiate from that point. It is often helpful to use three basic questions to organize the class discussion: What did we do? (Review the procedure.); What did we find out? (Review the data.); and What do the data mean? (Discuss conclusions and interpretations.). No one can predict exactly what questions will be asked during a discussion, but the questions should stem from the students' responses and questions. In many cases a student will suggest that the class collect additional data. Ideally, the teacher would affirm the request by allowing the students to do whatever necessary to better understand the concept being investigated.

Expansion Phase: Using the Data

The final phase, the **expansion**, provides varied opportunities for students to extend, generalize, and apply their knowledge of the target concept. This facilitates the organization of the students' thinking with other knowledge and experiences. One way to use the expansion phase is to pose a problem for which students generate hypotheses and design experiments to test those hypotheses. The form the expansion takes depends wholly on the teacher's intent and the students' interests. Field trips, speakers, integrated lessons, problem solving groups, readings, presentations, computer simulations and programs, and games can all be used with thoughtful scientific inquiries to provide the students with a well-rounded understanding of the concept.

The thinking encouraged during the expansion phase of the learning cycle is significantly different from that of isolated activities. It is not enough for students to have experiences related to the target concept. It is not even enough for students to make sense of their data and arrive at the target concept. Students must also find connections between the concept and other experiences (NRC, 1995; Paul & Binker, 1990; Renner & Marek, 1988; Resnick, 1992; Roth, 1992). Expansion activities allow students to further consider the concept(s) of the investigation. Students begin this phase of a learning cycle with common experience and language about the target concept. Newly-formed ideas are available for testing and refining. The initial construction of the concept accomplished in the preceding phases can be developed into a more carefully considered construction. Clear indications of this thinking are expressed in student comments such as, "Oh, is that like ... ," "I wonder if [something else] works the same way," and "What would happen if we [changed the variables]?" Curiosity is essential for the development of connections among concepts; yet, in a recklessly-paced curriculum, teachers often refrain from encouraging students to wonder, "Why?" or "What if?" The expansion phase provides that necessary opportunity for students to ask their questions (satisfy their curiosity) about how and why the target concept is connected to other experiences and ideas. Students are asked to make sense of these expansion opportunities as they are experienced, providing for continual restructuring, or re-organizing, of the student ideas about the concepts. Well-designed assessments contribute to the expansion phase by providing an opportunity for students to put together all the ideas considered throughout the learning cycle.

During the exploration and invention phases of the simple machine learning cycle, the students find that the pulley, the lever, and the ramp (inclined plane) allow them to lift an object using less force than they could without using the simple machines. The context for the investigation thus far has been classroom related. To move the context to a more everyday setting the teacher can begin the expansion by asking students to list and draw all the simple machines they see in the classroom. A relevant homework assignment would be for the students to help with dinner preparations and make a list of all the simple machines they use when they prepare and consume food. The lists could be posted on a permanent chart in the classroom (Example machines: door, pencil sharpener, pencil, stairs, ramps, chalk, can opener, knife, spoon, and fork).

An open-ended student investigation that will provide context and enhance community awareness involves a project focusing on the following question: Why are the ramps for physically challenged persons so long? The students can begin by making measurements of access ramps around the school. Measurements would include the length of the ramp and the distance between the ground and the door sill. The angle of the ramp could also be measured. Data concerning the length and height of stairs would also provide important information for later discussions (if stairs are available near the ramp). If time and transportation permit, a field trip to measure other ramps in other buildings (perhaps city government facilities) would be appropriate. Back in the classroom the students would be asked to organize, present, and review their data and to make some predictions (mini-hypotheses) concerning the reason for the large differences between the length of the ramps and the height of the door above the ground. The teacher can provide ramps (1" by 4" boards) of varying lengths for the students to use to try out their ideas. Students would be required to keep a record of their ideas, their actions, and their data. After a few days of open investigation, the students would be asked to organize their data into a report for the class. Drawings and data charts from the students' investigations can be posted on the walls for others to view. The class will discover that the longer a ramp is, the smaller the force needed to move an object up the ramp. This is a good place for the teacher to help students build upon their understanding of simple machines. While the students will have found that simple machines let them put in less force to raise an object, there is a trade-off—they have to lift the object over a greater distance (This learning cycle is titled "You Can't Get Something for Nothing!"). A speaker could be brought in to discuss with students the way products for physically challenged persons are conceptualized and invented. Perhaps students will want to draw their ideas about inventions for use by persons with particular challenges.

As an assessment for the investigation, students return to the initial problem: getting the bag of cement into the teacher's car trunk. The assessment could be individualized, but a group "test" would be more appropriate. The teacher would ask students to make new drawings about the way they would get the cement into the car trunk and provide an explanation for their illustrations. The explanations could be given to the teacher in an oral format or could be written down by one of the students in the group. Tape recorders work well for group assessments; students discuss their answers, make a few notes, and then talk their answers into the recorder for the teacher to hear later. Students are encouraged to support their opinions with data from the investigation of simple machines.

At this point we want to emphasize the need for realistic expectations. Students in a third grade classroom think and act like third graders. Lengthy discussions without breaks or an overemphasis on getting everything "just right" will certainly result in frustration and (likely) disruption. We taught this learning cycle in a third grade classroom. We are confident that the students can collect the data, invent the concept during a whole class analysis of those data, and perform open-ended explorations to expand their understandings of the concept. The process, however, requires the patience of the teacher and ample time for the messy work that scientific investigation really is. The teacher must also be aware of the level at which the students are thinking and work within that "zone." The classroom environment is relaxed, but not lax; flexible, but not undisciplined. We have found the end result to be an enjoyable experience for the teacher and the students.

Summary

As the national emphasis in science education moves from book-oriented to experience-oriented science, a concomitant need exists to provide more than just "hands-on" science. Hands-on science is a definite improvement over science instruction that emphasizes information in textbooks and on worksheets. Although clearly necessary, hands-on activities alone are not sufficient. That notion is validated through the increasing publicity given to what is now called "hands-on, minds-on" science (Hackett, 1992). We have all learned from our own experiences with children that putting hands on something (like the person in the adjoining desk) is not sufficient to provoke the development of deep, reflective contemplations about scientific phenomena. Social interactions, thoughtful reflections, conjectures, predictions, and hypothesis testing will provide students with a stable conceptual base and ultimately a deeper understanding of the science concepts. The learning cycle provides an instructional vehicle for students (and their teachers) to develop, test, and build upon wonderful ideas that come about when in-depth, student-centered investigations are the focus in the science classroom.

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Chapter 6

Weather Activity Sequences for Conceptual Development

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& Meta Van Sickle

Guiding children's conceptual development can often be a difficult process. Children are quick to figure out what the teacher wants as the "right answer," without understanding the underlying concepts or why that is an acceptable answer. This chapter presents a paradigm that early childhood educators can use to develop activity sequences to teach science process skills and related mathematics skills, as well as help children answer why. This paradigm draws upon the current knowledge and beliefs in science and early childhood education, and it allows teachers to apply the activity sequences to various content or thematic topics. The philosophical basis for this paradigm is constructivism.

Constructivism

Constructivist practice takes many forms in the classroom, but at the heart of the forms of constructivism lies the notion that understanding is built in individual human minds. Williams and Kamii (1986) define constructivism as the formation of knowledge through acting on an object or the environment. Children are particularly adept at building meaning in their world; sometimes the meaning is agreeable and sometimes the meaning is not agreeable to the adult communities surrounding the children. Preschool, kindergarten, and most primary grade children are pre-logical in their thinking. Young children sometimes explain things using a combination of their intuitive thinking and misapplied information. Regardless of the meaning that children form about a subject, concept, or process, the understanding that the children create is real to their experiential world.

Piaget and Vygotsky were early psychologists who helped shape current constructivist thought. Piaget defined age dependent stages of ability from thinking in a sensory motor mode through the ability to think abstractly. Movement through these stages is not automatic. Young children need many experiences so that they can create meaning and further develop their thinking abilities. Thus, it is very important that young children be exposed to an enriched environment that challenges their current thinking (Staver, 1986). Vygotsky was more concerned with social construction of knowledge. Children must learn to share, communicate, and thus work together. The Vygotskian tradition led to social constructivism that incorporates the same ideas as Piaget's individual constructivism and then adds the interaction of children. Children, plural, is the operational imperative in social constructivism. Children interact, and then children create meaning. The teacher's role is to determine the meaning the children have created to explain various concepts, processes, or skills.

Constructivist teachers encourage children to think aloud, and give verbal or pictorial descriptions of their current thoughts. After constructivist teachers discern the children's meaning, the teachers deliberately challenge the children's thinking. Teachers direct questions to the children in a fashion that causes the children to rethink, discuss, and negotiate new meaning(s) (Kasten & Clarke, 1991). Another tactic teachers might choose would be to provide discrepant events that the children encounter as a group, and view the same phenomenon from a variety of perspectives. The children are required to think about and discuss open-ended questions such as, "What did you see?" and "How does your previous answer fit with this explanation?" Thus, the children have the task of creating meaning, and the teacher has the task of encouraging the children to evaluate current meanings. The children then attend to new experiences while the teacher asks thinking questions that generally encourage children to restructure or form a more sophisticated explanation of the concept, process, or skill. When consensus is reached, a socially construed understanding has been developed (Gergen, 1995).

Constructivism emphasizes the importance and interrelatedness of concepts, skills, and attitudes in children's learning and development. Katz and Chard (1989) identify these same aspects as knowledge, skills, and dispositions. These early childhood educators also emphasize the development and enhancement of the whole child in order to promote learning and conceptual development. In teaching the young child, sensory input and movement is a critical aspect of learning, as these have been the major modes of learning for the first two years of life. Language and interaction with other perspectives also move into primary modes as children become three and four years of age. During the early childhood years, children begin to understand that written symbols are used to represent objects and ideas. Children expand their thinking and modify their logic on (a) sensory input, (b) interaction with manipulatives and thinking about their actions, and (c) their experiences and encounters with different perspectives. Young children begin to see relationships among concepts only if they are able to interact and think about objects and things that they can manipulate (Clements & Battista, 1990; Williams & Kamii, 1986). Through interaction with others, experiences over time, and learning more about their world, children begin to move into logical thinking.

Building on Interests and Life Experiences

The constructivist teacher is aware of the importance of building on and making connections to the child's knowledge and experiences, or scaffolding. By knowing the range of new experiences and knowledge that each child can grasp and understand, the teacher can assist the child to make connections (Berk & Winsler, 1995). Each child is unique in her or his abilities, experiences, and perspectives of the world. The effective teacher understands each child, and facilitates his or her development by providing experiences that broaden and alter the conceptual understandings.

The constructivist educator must continually assess the children's intellectual development, select tasks and experiences which are appropriate for the children, analyze children's responses in terms of developmental criteria and understanding (along with content), and promote cognitive development through interaction with materials, experiences, investigations, and other children. The teacher presents experiences, learning activities, and investigations that are relevant to the developmental stage and interests of the children, thereby nurturing children's natural curiosity. Raw data and primary sources, along with manipulative, interactive, and physical materials are used for learning activities with the children. Child autonomy and initiative are encouraged and accepted.

5 Es Paradigm

We have built on past research and work in the field of science education (Science Curriculum Improvement Study, 1976; Thier et al., 1986; Trowbridge & Bybee, 1996) and developed a paradigm that can be used to promote conceptual understandings and "scientific literacy." We have modified Trowbridge and Bybee's (1996) model into both a planning (unit planning) and an instructional (learning activity sequence) paradigm. The presented paradigm is based on both individual and social constructivist views of learning. A constructivist paradigm, like this one, is inconsistent with many examples in the literature which present

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completed, detailed, lesson plans. A truly constructivist model must be dynamic and fluid, since it is dependent on the constructs children form during interactions with materials, environment, and peers.

The five phases of the presented paradigm are: engagement, exploration, explication, elaboration, and evaluation (5 Es) (See Figure 6.1). The first phase is that of *engagement*. This initiates the learning process when interest and curiosity in the topic are generated. This phase makes connections to the past and future activities. Questions are raised about the topic and activities. These initial activities should be concrete and engaging.

The second phase is *exploration*. Exploration provides experiences that include the concepts, processes, and skills important to the topic. The topic is explored through investigations, manipulations, and open-ended problem-solving. Children are allowed some freedom to explore and manipulate problems presented by the teacher. This phase emphasizes active, open-ended investigations by the children, not demonstrations by the teacher.

The third phase, that of *explication*, is when vocabulary, terminology, labels, definitions, and explanations are initially brought into this cycle. Children focus on specific experiences, discuss them, and are formally introduced to concepts and labels. Discussion of the topic includes justifications and clarifications of the varying perspectives and findings that arose during the exploration phase. Children are the main contributors to the discussion.

The fourth phase, *elaboration*, includes active use of the newly learned concepts, skills, vocabulary and applying the knowledge to new situations or extending it to other, appropriate

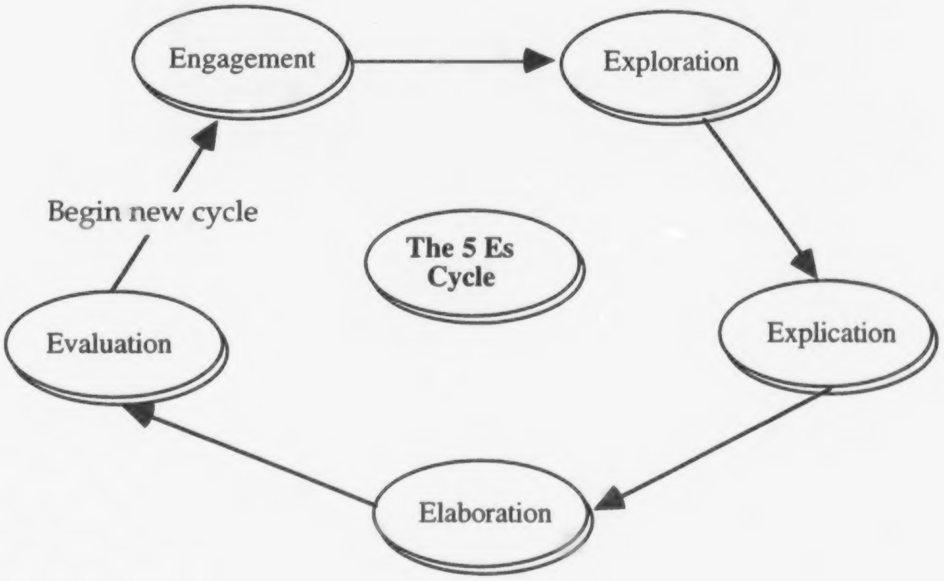

Figure 6.1 *The 5 Es cycle*

situations. Interrelated experiences that extend the children's understandings and applications of concepts, processes, and skills are presented. New and different experiences develop deeper and broader understandings. Elaboration includes both application of knowledge, skills, concepts, and vocabulary, along with extension, transfer, and generalization of these knowledge and skills.

The final phase, *evaluation*, focuses on assessment. Authentic activities are used to assess the children's understandings and abilities. Children are also encouraged to assess their own progress. The extent to which the topic has been learned and new directions for further investigation are determined. General attitudes and behaviors towards working with others and investigating problems are also assessed. Figure 6.2 provides guidelines for assessing children's general science skills and attitudes.

Performance Indicator	Evidence / Criteria
Following directions	Child follows the directions.
Measuring and recording data	Measurements are reasonably accurate and include correct units.
Planning	Child organizes the work appropriately.
Elegance of approach	Child invents a sophisticated way of collecting, recording, or reporting observations.
Evidence of reflection	Child comments on observations in ways that indicate that he/she is attempting to find patterns and causal relationships.
Quality of observations	Observations are appropriate to the task, complete, accurate, and have some basis in experience or scientific understanding.
Behavior in the face of adversity	The child seeks help and does not panic if sand, water, or other materials are spilled, but proceeds to clean up, get replacements, and continue the task.

Figure 6.2 *Criteria for assessing children's performance*
(from National Research Council, 1996)

This 5 Es paradigm emphasizes physical interaction with materials and interpersonal interaction with teacher and peers. The 5 Es also includes vocabulary and language development which enhances young children's conceptual advancement. The basic science processes of observation, classification, communication, and measurement, are stressed throughout the paradigm. The authors view the 5 Es paradigm as a guide, for teacher planning and implementation, to enhance conceptual development through appropriate learning experiences for children.

Science process skills provide a basis in the logical disciplines for children to understand their world and the natural phenomena in it (National Research Council, 1996). For young children, emphases on the basic process skills of observation, classification, communication, and measurement are of critical importance. These processes are essential for children to describe and think about objects and events, to communicate with one another, and to explain and understand different perspectives. Expanding children's communication and language skills significantly augments their thinking and conceptual development (National Council of Teachers of Mathematics, 1986; Perlmutter, Bloom, & Burrell, 1993). Providing meaningful experiences with concept and language enhancement, also allows children to connect vocabulary terms with activities, processes, and attitudes (Flick, 1993; Kilmer & Hofman, 1995).

Therefore, in setting up and establishing the classroom environment and learning activity sequences, there are several issues to be considered:

1. Children learn through hands-on, minds-on activity.
2. Children need to be able to make choices.
3. Children focus and attend best if the learning is related to their interests.
4. Children learn in an integrated fashion. The curriculum areas are not separated in life or in the minds of young children.
5. Children need interaction with others to confront differing ideas and to realize that there are other opinions and perspectives.
6. Children need interaction with others to determine common understandings and transmission of culture.
7. Children need broad and extended bases of experiences.

Developing Learning Activity Sequences

The 5 Es provide a template for planning learning activity sequences within a unit of study. The emphasis is on children actively learning and the teacher facilitating. In an activity sequence, the first phase, engagement, focuses children's interest and attention on the topic. In the exploration phase, children actively explore the topic and manipulate materials relating to the topic. In the explication phase, the children learn about the concepts and a formal vocabulary is provided by the teacher and attached to these concepts. During elaboration, the children apply and extend the newly developed concepts. In the final phase of evaluation, children reflect on the concept and vocabulary; and their understandings are assessed by the teacher. The definition of the five phases reflect this transfiguration as follows.

Engagement

This phase initiates the learning task. This phase should (a) make connections between past and present learning experiences, and anticipated activities and (b) focus children's thinking on learning outcomes. The children should become mentally engaged in the concepts, processes, or skills to be explored. This portion of the lesson plan focuses on the learner and learning. Thus, focusing on what the child is experiencing and learning is imperative for conceptual development.

Exploration

This phase provides children with a common base of experiences within which they identify and develop current concepts, processes, and skills. During this phase, children actively explore their environment and/or manipulate materials. The children also discuss the different extents of their findings within small groups.

The teacher inquires about children's understandings of concepts in order to ascertain in which direction and on which levels to proceed with learning activities. The teacher probes into children's levels of reasoning, asking for justification and then exposes the children to differing points of view through experiences, tasks, learning activities, and investigations. Children are encouraged to record their data in notes, on charts, or in picture form. The teacher engages the children in experiences that might engender contradictions to their initial responses and then encourages discussion.

Explication

This phase of the sequence focuses children's attention on a particular aspect of their engagement and exploration experiences and provides opportunities for them to verbalize their conceptual understanding, or demonstrate their skills.

This phase also provides opportunities for teachers to introduce vocabulary, formal labels, or definitions for the concepts, processes, or skills explored in the previous phase. The teacher asks questions and translates children's words to science terms or formal labels. The teacher may encourage children to talk with one another and develop further explanations. (This is not an appropriate place or paradigm for lectures.)

During discussion, the teacher introduces content vocabulary and specialized terms. At this point, cognitive and science terminology such as "observe" and "classify" are used when framing additional tasks and investigations. The teacher encourages children to engage in dialogue with one another. The teacher also encourages critical thinking by asking thoughtful, open-ended questions, and encouraging children to ask questions of each other. Sufficient wait time is allowed after posing questions to allow for thoughtful answers, and to provide time for students to construct relationships and create metaphors.

Elaboration

Children's responses are used to drive lessons, shift instructional strategies, and alter content. Subsequently, the teacher sets up experiences, tasks, and activities that require the children to apply and transfer this newly grasped understanding. The children work predominately in small, heterogeneous groups, so that they encounter other opinions and points of view. The experiences and tasks are related to the children's lives, and are meaningful and of interest to them.

This phase challenges and extends children's conceptual understanding and allows further opportunity for children to apply concepts, processes, or skills to a novel application. Through new experiences, the children develop deeper and broader understanding, gain more information, and strengthen skills.

Evaluation

Lastly, the constructivist teacher assesses children's understandings through meaningful tasks (Brooks & Brooks, 1994). Assessment is intertwined with instruction, and includes assessment of children's: problem-solving, record-keeping, work with materials and peers, and analyses of thinking processes. Assessments results also provide information useful for further planning (Hein & Price, 1994).

This phase of the sequence encourages children to assess their understandings and abilities. The teacher evaluates concept, skill, and process development by assessing what the child has understood and accomplished. This will guide further explorations to meet educational objectives or curricular goals. It is important to note, that if some children have not adjusted or revised their thinking, this concept may be beyond their "zone of proximal development." Teachers need to allow children's "logical" thinking and responses, even if they are incorrect. Later investigations, interactions, experiences, and developmental learnings may alter the thinking of these children. To coerce them into mouthing the generally accepted reality may force their true beliefs underground where they are not available to transformations or modifications through explorations.

When implementing the 5 Es, it is helpful to keep in mind the role of the teacher and the role of the children. For example, do not force a "correct" response. If children are "told" an answer or explanation, they mimic this in their responses without modifying or adapting their thinking (schemas). We have found that separating what the child is to do from what the teacher is to do ensures that the child is involved in active experiencing. Other clarifications are listed in Figure 6.3.

One way to assess the overall activity sequence is to develop a checklist that includes the following points:

- Is the topic interesting to children?
- Is the topic interesting to me (the teacher)?
- Is the activity sound in terms of curriculum and content?
- Are there adequate resources for this activity sequence?
- Will the activity sequence engage children at different levels of abilities?
- Are there strong cross-curricular connections?
- Are there sufficient opportunities for children's input to guide or determine direction?
- Is there an emphasis on oral and written language development and communication?

The 5 Es learning activity sequence planning template facilitates conceptual development through interactions with materials, teachers, and peers. (Note: If you are unable to determine an activity for a concept, some possible resources are: another teacher [middle and secondary teachers are also useful as content consultants], activity books in the library, National Science Teachers Association journal *Science and Children*, other journals for teachers of young children, and ERIC documents.) When working with young children, most learning activity sequences should be exploratory in nature.

To illustrate application of the learning activity sequences, we have developed a unit on weather. The aspects of weather that we have chosen for the children to explore are wind, temperature, the water cycle, and weather trends. Within each of these major categories, we

Teacher Behavior	Child Behavior
Engagement - create interest in topic - raise questions - elicit what children think about the topic - cause curiosity	**Engagement** - show interest in topic - ask questions
Exploration - encourage children to work together - observe and listen to children - asks questions to redirect children	**Exploration** - think freely about topic - suspend judgment and try alternatives - record observations and ideas - discuss ideas and experiences
Explication - have children explain in own words - have children define in own words - ask for justification from children - use children's previous experiences and understandings to explain concepts - provide definitions, explanations, clarifications, and formal labels	**Explication** - explain possible solutions to others - use observations and data in explanations - listen critically to others' ideas
Elaboration - encourage children to apply and extend learnings to new situations - remind children of alternatives - expect children to use formal labels - remind children of existing data and evidence - ask "What do you think?" "Why?" - encourage children to work together - ask questions to redirect children	**Elaboration** - apply new learning in new but similar situations - use newly learned terminology - ask questions, propose solutions, design investigations - make reasonable conclusions from evidence - record observations and explanations - discuss investigations and conclusions with peers
Evaluation - observe and record as children apply new learnings - look for evidence that children have changed their thinking - guide children to also assess own learning - ask open-ended questions to assess children's reasoning	**Evaluation** - evaluate own progress and learning - demonstrate reasonable understanding of new learnings - apply observations and evidence to answer open-ended questions

Figure 6.3 *Implementing the 5 Es learning activity sequence*

identified several concepts (utilizing national science and mathematics standards, and state science and mathematics standards) as important for children to understand. These are:

Wind
- directionality
- moves things
- speed

Temperature
- feeling on skin
- cold, warm, chilly, etc.
- thermometer
- degrees
- "reading" thermometer

Types of weather
- sunny
- rainy
- cloudy
- thunderstorm
- hurricane
- foggy
- tornado

Water cycle
- evaporation
- clouds
- humidity
- condensation
- dew
- fog
- frost
- precipitation types

The four learning activity sequences on the following pages illustrate how the teacher could use the 5 Es to plan and teach particular concepts for a unit on weather. The following activity sequences are presented:

Wind Activity Sequence
- Blowing Winds
- Wind Directions
- Speedy Winds

Temperature Activity Sequences
- Feeling Hot and Cold
- Measuring Air Temperature

Water Cycle Activity Sequences
- Condensation
- Water Cycle

Weather Trends Activity Sequences
- Foggy Days
- Daily Weather

Wind Activity Sequence

Blowing Winds

What the children do

Engagement
Watch a fan that is blowing streamers.

Exploration
Watch the fan blow the streamers at slow, medium, and fast speeds.

Hold streamers on different sides of the fan (at a distance). Determine which streamers blow, and in which direction. Draw pictures of the fan, wind, and streamers.

Explication
Children explain the direction and the speed the streamers are blowing based on the direction and speed the wind from the fan is blowing.

Elaboration
Examine the wind blowing objects outdoors (streamers, leaves, grasses, dust, etc.).

Evaluation
Children move like an object being blown by the wind.

What the teacher does

Engagement
Set up a fan to blow streamers tied to the grill indoors.

Exploration
Have the children watch the fan blow the streamers at slow, medium, and fast speeds. Have children hold streamers on different sides of the fan (at a distance). Ask: Which streamers blow, and in which direction? Which direction is the wind blowing? Which direction are the streamers blowing? Have the children draw pictures of the fan, wind, and streamers.

Explication
Have the children explain the direction and the speed the streamers are blowing and how they relate to the direction and speed the wind from the fan is blowing.

Elaboration
Take the children outdoors to examine the wind blowing objects (streamers, leaves, grasses, dust, etc.).
Ask: Which direction is the wind blowing? How do you know the wind is blowing in that direction? What other objects are blowing in the wind? Are they blowing in the same direction?

Evaluation
Have the fan blowing without the streamers. Ask the children to stand in the wind and to use their arms as if they were limbs on a tree. They should be able to show the direction and type of movement that tree limbs would make when blowing in the wind. The teacher may move the direction the "wind" is blowing to corroborate directionality, and may change the speed of the "wind" to see if children make their arm wave more in stronger "wind."

Wind Directions

What the children do

Engagement
Children take compasses and go outside with them. They experiment with the compasses.

Exploration
Children point their compass north and set it on the ground in front of them. Children turn to face the wind, so that it blows straight into their face. They will notice the direction that they are facing (they will read the compass).

Explication
Children explain the direction the wind is blowing based on the direction they are facing and their reading of the compass.

Elaboration
Repeat the investigation and determine the direction the wind blows for several days. In pairs, the children can list or chart the days and wind direction for the week.

Evaluation
Draw the direction of the wind.

What the teacher does

Engagement
Explain to children that compasses help us to determine direction. Explain how the compass works and N, S, E, W. Have enough compasses for each child or pair of children. Take the children outside on a windy day.

Exploration
Help the children line up their compasses with North and set them on the ground. Have the children turn their faces into the wind.
Ask: Which direction is the wind blowing from? Which direction (compass letter) is the wind blowing from? What else is the wind blowing that helps you determine where is it blowing from (trees, etc.)?

Explication
Have the children explain the direction the wind is blowing from and how they determined the direction.

Elaboration
Take the children outdoors to determine the direction the wind blows for several days. List or chart the days and wind direction for the week.

Evaluation
Have the children draw the direction of the wind. One sample can be used each day for class weather charts. Other papers can go in a book that the children are making about weather.

Speedy Winds

What the children do

Engagement
Children look at anemometers (official or homemade). They experiment with the anemometers by blowing against the front and back of the cups.

Exploration
Children take the anemometers outside and determine if the wind makes the anemometers move.

Explication
Children describe how fast the wind is blowing. At slow speeds, the children can count the number of turns the anemometer makes in a minute.

Elaboration
Children further investigate the wind speed by observing how the wind is affecting blades of grass, leaves, and branches of trees.

Evaluation
Illustrate the effects of wind on blades of grass, leaves, and branches of trees atthe different wind speeds.

What the teacher does

Engagement
Provide several anemometers (purchased or homemade) for the children to look at and experiment with by blowing against the front and back of the cups.

Exploration
Have the children take the anemometers outside and determine if the wind makes the anemometers move.

Explication
Ask the children to describe how fast the wind is blowing. Can they count the number of turns the anemometer makes in a minute? Can the children blow as fast as the wind is blowing? Is the anemometer turning fast, medium or slow? How can they tell? Tell the children that they are using an anemometer, and that this is a tool that measures wind speed. Have the children describe how it works.

Elaboration
Take the children outside with the anemometers on still days, on slightly windy days, and on very windy days. Have the children explain how fast the wind speed is on each of these days. How does the anemometer react?

Have the children further investigate the wind speed each day by observing how the wind is affecting blades of grass, leaves, and branches of trees. Have the children examine the wind speed using the Native American tradition:

No wind = no leaves or branches moving.
Slight wind = leaves and grass blades gently waving in the wind.
Medium wind = small branches and bushes gently bending in the wind.
Strong wind = medium branches bending in the wind and grass blades bent over in the wind.

Evaluation
Have the children illustrate the effects of wind on blades of grass, leaves, and branches of trees at the different wind speeds.

Temperature Activity Sequences

Feeling Hot and Cold

What the children do

Engagement
Using warm, room temperature, and cold liquids, children order the liquids by warmest to coldest (serial classification).

Exploration
Children use thermometers. Children note where the red line on the thermometer is for room temperature.

Children record if the red line inside the thermometer is higher or lower as they place it in different containers.

Children observe the red lines in thermometers to see if their earlier serial classification by touch show that the height of the red line changes accordingly if temperature is cold or warm.

Explication
Children explain what the red line indicates about warmth or coldness of the liquid. Teacher explains that the instrument they are using is a thermometer. Children explain what the thermometer measures.

Elaboration
Children can measure the temperature of other objects, liquids, and gases. Children select the objects to take the temperature of and then draw a read line on the paper that matches the red line on the thermometer. Children then serial order the temperatures of solids, liquids, and gases in the room.

Evaluation
Children "measure" the temperature of novel objects such as an ice cube, and a container of orange juice that has just been removed from the refrigerator. Children serial classify the order of the temperature of the objects from hottest to coldest.

What the teacher does

Engagement
Provide a minimum of three containers of water for each pair of children (one cold container, one warm or room temperature container, and one hot [not too hot) container of water].
Ask: Which liquid is coldest? Hottest? What sense are you using to decide how hot or cold the water is? Tell children to arrange containers from hot to cold.

Exploration
Provide each pair of children thermometers. (Make sure to use large, safe, easy to read thermometers.) Have children note where the red line on the thermometer is for room temperature.

Have the children set thermometers in the liquids. Children record if the red line inside the thermometer is higher or lower as they place it in each container.

Children observe the red lines in thermometers to see if their earlier serial classification by touch show that the height of the red line changes accordingly if temperature is cold or warm.

Explication
Ask: How long is the red line when the liquid was cold? How long is the red line when the liquid is warm? Do you think the length of the red line stays the same all the time? Explain that the instrument they are using is a thermometer. Have the children explain what the thermometer measures.

Elaboration
Make sure that other solids, liquids, and gases are available so that children can take the temperature.

Have children draw a red line on the paper that matches the red line on the thermometer. Ask the "explain" questions again.

Have children serial order the temperatures of solids, liquids, and gases in the room.

Evaluation
Select novel objects that the children haven't yet measured the temperature and have not previously serially classified according to temperature. Have children indicate serial order based on touch and then by adding the technology of a thermometer.

Measuring Air Temperature

What the children do

Engagement
Children explain how they know if it is hot or cold outside.

Exploration
Children experience thermometers and measure the temperature of their hands and of the air. Children measure the temperature outside the classroom and compare to earlier temperatures.

Explication
Children tell what hot, warm, and cold feels like. Children tell what hot, warm and cold looks like on the thermometer.

Elaboration
Children keep a chart of daily room temperature and outdoor temperature. Children graph the weekly and monthly indoor and outdoor temperature. Eventually children can graph the temperature for the seasons during the school year.

Evaluation
Towards the end of the school year, children tell the temperature patterns of the seasons.

What the teacher does

Engagement
Distribute thermometers to children. Tell children that they get to use these tools today.

Exploration
Show children where to hold the thermometer, and how to read the red line. Have children hold the bulb between their hands and observe what happens to the red line. Have children hold the bulb in the air to determine room temperature. Take the children outdoors. Have children hold the bulb in the air to read the outside temperature. Have children (if able) write the inside and outside temperature on a previously prepared chart.

Explication
Ask, "Is the temperature the same or different inside and outside?" Tell the children that these tools are called "thermometers." This tool is used to measure temperature, or how hot or cold something is. (Write thermometer on board.)

Elaboration
Continue taking indoor and outdoor temperatures daily.
Ask: Which season is coldest outside? Hottest outside? What kind of weather is outside when it is hottest? Coldest?

Evaluation
Have children draw a picture of a cold, warm, and hot day outside.

Water Cycle Activity Sequences

Condensation

What the children do

Engagement
Early in the morning at the start of school, children examine the wet grass. Children examine the exterior wetness of their snack or lunch time cold drinks.

Exploration
Children investigate several containers with warm liquids, room temperature liquids, and cold liquids. Both clear and colored liquids are provided both warm and cold. Children write or draw their observations using the five senses. If children are unable to write or draw, a list of the children's spoken words can be created. (Children can taste the water on the outside of the container [and the contents] to determine if it is the same liquid that is inside the container.)

Explanation
Children explain how the water, condensation, was formed on the container. Children will learn vocabulary of "condensation," "dew," etc.

Elaboration
Children decide how they might further investigate condensation. They conduct many other investigations and record (with teacher assistance) their findings.

Evaluation
Children determine what they learned. Children will present their findings, or brainstorm what they learned, and the teacher writes it down. Children draw pictures of condensation. If some children's conceptions remain naive, allow them further experience with condensation across the school year.

What the teacher does

Engagement
Say, "Touch the grass, and tell me, what do you feel?" Later in the morning, the teacher directs students to observe again, and asks, "What do you feel on the outside of your drink box?"

Exploration
Provide a variety of warm and cold liquids in clear glass and plastic containers (water, cola, milk, tomato juice, etc.) Make sure the drinks are visible and the products (e.g., cold, milk, etc.) are known. One container of each liquid will be at room temperature while the other will contain very cold liquid. Both clear and colored liquids are required, so children can further explore if they assume that the container leaks. Then ask, "What do you feel on the outside of the container?"

Encourage the containers to be touched and compared. Ensure that all five senses are used. Encourage written, drawn, and spoken responses. (Young children may not be able to record their observations, but the teacher may break the investigation into steps, and the children can voice their observations at each step and the teacher can record these.)

Ask guiding questions such as, What does the outside of the container feel like? Which containers are wet? Are only the cold containers wet on the outside? Are the warm/room temperature containers also wet on the outside? What does the liquid taste like? Is it the same liquid that is in the container? (This helps dispel the notion that the container is leaking.) Accept all answers and ask further questions to help clarify observations. Children's answers should be collected in some format.

Explication
Ask questions such as, What is on the outside of the container? What temperatures allowed the water to form on the outside of the container? Where did the water come from? What does it mean when we say there is water is in the air? Ask the children to explain their thinking, and provide children with the appropriate vocabulary and labels for the concept being explored (e.g., dew, condensation, humidity).

Elaboration
Assist children in deciding how they might want to further investigate condensation. Perhaps the children want to see if cold solids also cause condensation (e.g., flour, cold rocks). Perhaps other liquids should be investigated. Perhaps children want to determine if light or darkness affects condensation. These investigations are then set up. Have the children observe and record their findings, and compare these findings to those during the exploration phase.

Evaluation
Have the children determine what they learned. Perhaps the children will present their findings, or brainstorm what they learned, and the teacher writes it down. If some children's conceptions remain naive, then allow them further experience with condensation across the school year.

Water Cycle

Water Cycle Chorus:

Rain falling down,
Back to the ground,
Streams going by,
Back to the sky,
Water cycle, water cycle, water cycle.

What the children do

Engagement
The chorus of the song, "Water Cycle" is playing. Children are listening and learning the words.

Exploration
Children begin making motion to fit the words. Children draw pictures of a circle, cycle. Children draw a stream, clouds, and rain. Children draw a circle that attaches these things together.

Explication
Children show motions or draw pictures to illustrate a cycle. Children tell in their own words, what a cycle is.

Elaboration
Children tell stories about getting caught in a rain storm, or how humid it is today. Children tell stories about steam rising from pots of boiling water, or fog on the lakes and rivers in the morning.

Evaluation
Children tell or draw a water cycle story.

What the teacher does

Engagement
Play the chorus of the song "Water Cycle" repeatedly. Teach the children the words to the chorus.

Exploration
Encourage the children to create movements to match the words of the song. Supply paper and crayons so that the children can draw a cycle or a circle. Ask the children about water in the air, from the previous activities on condensation. Ask what a lot of water looks like and feels like. Ask about rain, what is rain, how does rain happen.

Explication
Ask, "What is a cycle? Rain falls down to ...? The streams and creeks run to ...? The water goes to ...?" Ask for a circle to be drawn so that these items are attached.

Elaboration
Show a tea kettle boiling, with steam coming out of the spout. The teacher holds a cookie sheet over the steam. The teacher asks for observations about water in the sky, about water condensing on the cookie sheet, about water falling off the cookie sheet.

Evaluation
Have the children create a drawing to illustrate the miniature water cycle created by the tea kettle.

Weather Trends Activity Sequences

Foggy Days

What the children do

Engagement
Children stand in the fog and observe with all their senses.

Exploration
Children write or draw their observations. Other days children look at clouds in the sky and observe.

Explication
Children speculate what fog is made up of, how it formed, and why it is on the ground instead of up in the sky.

Elaboration
Children share information about driving through fog, fog on the mountains, over the rivers, and over the lakes. Children share information about airplane trips that they have taken through the clouds.

Evaluation
Children draw or explain similarities and differences between fog and clouds.

What the teacher does

Engagement
Have the children stand in the fog and make observations. Go inside and record the observations for the children.

Exploration
Have the children write or draw their observations.

Explication
Tell children that fog is a cloud on the ground instead of up in the sky. Ask children what fog is made up of, how it formed, and why it is on the ground instead of up in the sky.

Elaboration
Have children share information about driving through fog, fog on a mountains, fog over rivers, and fog over lakes. Have children share information about airplane trips that they have taken through the clouds.

Evaluation
Have children explain similarities and differences between fog and clouds.

Daily Weather

What the children do

Engagement
Each day the children go outside or look out of the window and draw the weather.

Exploration
Children measure the temperature outdoors each day at the same time. They graph the temperature, and draw a picture of the weather.

Explication
Children describe the weather each day. Children explain the water cycle and what is happening outside that relates to the water cycle.

Elaboration
Children examine weather patterns by looking at the temperature and precipitation charts that they have made. Children will describe weather patterns by the seasons.

Evaluation
Children name and draw the type of weather and temperature on several school days.

What the teacher does

Engagement
Each day, have the children go outside or look out of the window and draw a picture of the weather.

Exploration
Have the children measure the temperature outdoors each day at the same time. Have the children graph the temperature and draw a picture of the weather.

Explication
Have the children explain the weather each day. Children explain the water cycle and what is happening outside that relates to the water cycle. Ask: What part of the water cycle are you seeing when the water is falling from the clouds? What do we call water falling from the clouds? What do we call frozen water that falls from the clouds? What part of the water cycle is happening on a clear day?

Elaboration
Have the children examine weather patterns by looking at the temperature and precipitation charts that they have made. Have the children describe weather patterns by the seasons. Draw the season lines on the charts or the children can state where they believe the season lines should go. (Repeat this lesson throughout the year.)

Evaluation
Have the children name and draw the type of weather and temperature on several school days. One sample can be used for class charts. Other papers can go into a book that the children make about the weather.

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Because the phases are extremely flexible, the 5 Es paradigm is particularly good for affecting adaptations for various ability levels. During exploration, activities can be individualized easily to suit special needs. Also during the phase of elaboration, extension activities for individual abilities are easily developed. Another possibility that utilizes the inherent flexibility of the 5 Es paradigm is the ability to cycle from explication back to exploration when a child is not yet ready to apply the concept in the elaboration phase. Many children will remain in the exploration phase for an extended period of time. Figure 6.4 illustrates how a teacher may recycle among the phases in order to best meet the needs and abilities of the children. This can only be determined through observations of children's abilities and thinking processes.

Remember, this is a cyclical learning and instructional strategy. Teachers may choose to cycle between two or three phases before continuing. Some children may not progress beyond the exploration phase in understanding certain concepts based on their experiences and developmental level. The 5 Es is not a linear paradigm. The teacher can remain in one phase or can cycle between two or three phases. If, in the evaluation phase, the child or teacher sees a need for further development or application, they can easily recycle back to the phase that can be utilized to meet this perceived need. Sometimes a teacher cycles between exploration and explication, or among explication, elaboration, and evaluation, using different activity sequences each cycle. This flexibility allows the teacher to meet the individual child's needs and to develop specially tailored activity sequences.

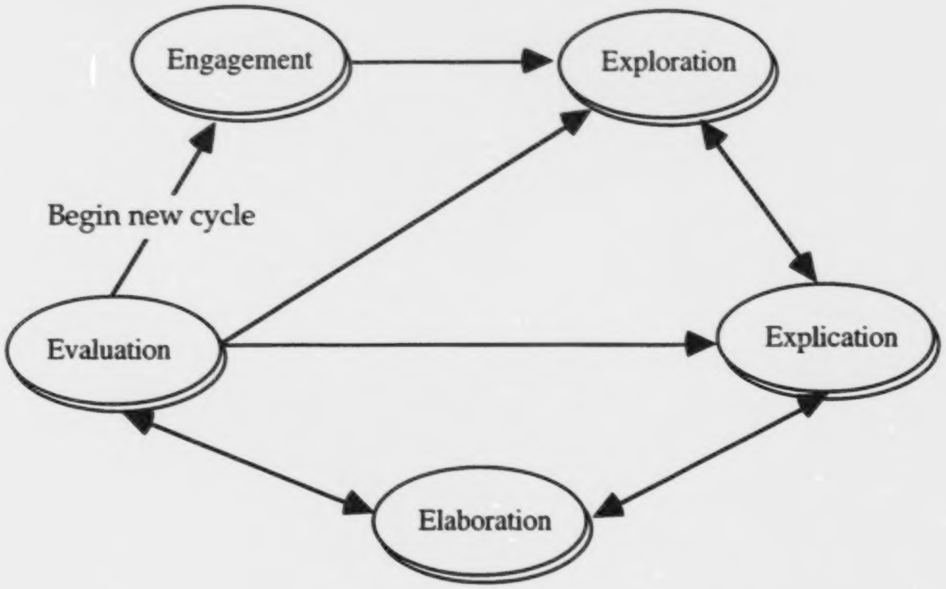

Figure 6.4 *Cycling within the 5 Es*

Conclusion

Educators need to remember that children share many behaviors with scientists as they are exploring and learning about their world. Through their experiences, they are developing concepts, skills, processes, and positive dispositions toward learning about their world. This 5 Es paradigm for planning units of study and instruction of learning activity sequences will assist teachers to guide children in discovering and correcting their naive theories. Through implementation of the 5 Es cycle—engagement, exploration, explication, elaboration, and evaluation—teachers can augment children's intellectual development based on understanding the underlying concepts and relationships among materials, the environment, and society. This paradigm takes into account the nature of the young child as a learner, the philosophy of constructivism (building on both science education and early childhood education), and the cyclical and spiral learning that occurs through learning activity sequences. When implementing the 5 Es paradigm, teachers will find that it is continuously evolving. Each phase is dependent on the one in front of it. Often, teachers will continuously recycle through the beginning phases, as the children need more experiences and explorations before they are ready to move on. The flexibility of this paradigm makes it unsuitable for the typical linear unit or lesson plan that can simply be copied for use in class. The 5 Es paradigm is learner centered and depends upon the learner and topics being addressed, as to how it may evolve for a particular group of children.

Throughout this chapter, the use of experiential happenings has been emphasized in the planning and implementation of instructional learning activity sequences. Hands-on, minds-on learning is needed for conceptual development. Because of the open nature of these experiences and investigations for young children, the ability of children to develop the concepts and skills to the degree they are capable of, is unlimited.

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Chapter 7

Earth Science for Early Childhood: The "Special Rocks" Activity

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In this chapter, we share a two-week long activity series on rocks that is appropriate for early elementary children. The purpose of the chapter is three-fold: (a) to share an activity series on rocks that is consistent with the goals of early childhood science education; (b) to demonstrate how written and oral pre-assessments can be used to guide the design of activity series; and (c) to show how outside resources (children's science books, professional scientists, and local companies) can be incorporated into activity series in ways that promote children's understanding of science concepts and process skills. Above all else, we hope that the descriptions and arguments we present will inspire teachers and researchers to collaborate to design and develop interesting and useful activity series for their own classrooms.

The first section of the chapter outlines the importance of incorporating knowledge about children's ideas into the design of activity series. We begin by describing how an activity series can be informed by and aligned with current goals for science education reform (AAAS Project 2061's *Benchmarks for Science Literacy*, 1993). Then, we briefly describe relevant research on children's ideas in science and present a method classroom teachers can use to inform their planning when developing activity series on topics that have not been extensively researched. We close the section by discussing how our pre-assessment of children's ideas impacted the design of the activity series.

In the second section, we outline the activity series on special rocks. This section provides sketches of daily lesson plans, including the objectives, questions for teachers to pose, descriptions of small group and whole class activity/discussions, materials and resources used, and homework. In the third section of the chapter, we reflect on various aspects of designing and teaching the activity series. The three teachers and two university researchers share their experiences with a unique process of curriculum design and instruction. Finally, we summarize our experience and encourage others to consider collaborating with colleagues and developing activity series for their own classrooms.

The curriculum development work described here was conducted within the context of the University of Delaware (UD)/Thurgood Marshall Elementary Science Lab Project. Supported by UD, the Christina School District, and Eisenhower, Title II funds, the science lab project is located at Marshall Elementary School. Teachers collaborate with the lab director (Betty Wier) and staff to develop and implement units that address district, state, and national science content standards and children's thinking about the topics. Pre and post assessments are conducted to determine changes in children's thinking about the targeted concepts. Units developed in the lab setting have been shared with teachers locally and at national conferences for science teachers (e.g., National Science Teachers Association).

Designing the Activity Series

Our activity series on special rocks helps children explore how rocks are formed and develop important skills needed to answer questions about Earth materials. The decision to focus on observing rocks and learning about their formation was influenced by our school district's curriculum guidelines, and informed by state and national science education documents and by research literature on the role of children's prior ideas in constructing understanding. In this section, we outline our method of integrating research literature, science education frameworks, and pre-assessment interviews with children into the design of activity series. The pre-assessment proved highly valuable since, as is the case in some domains of science, the research on children's ideas about rocks was rather sparse.

We started designing our activity series by looking at our school district's curriculum guidelines, the state science education standards under development (State of Delaware, Department of Public Instruction, 1995), and Project 2061 Benchmarks (AAAS, 1993). These guidelines emphasize studying the make-up and variation in rocks in early childhood. We also noted an emphasis on the Earth as a dynamic system and on broad themes in science, such as the nature of scientific inquiry and exploring change. For example, we selected the following benchmarks for K-2 science learning produced by the AAAS Project 2061 (1993):

Scientific Inquiry (Benchmark 1B)

- People can often learn about things around them by just observing those things carefully, but sometimes they can learn more by doing something to the things and noting what happens.
- Tools such as magnifiers, rulers, or balances often give more information about things than can be obtained by just observing things without their help.
- Describing things as carefully as possible is important in science because it enables people to compare their observations with those of their peers.

Processes that Shape the Earth (Benchmark 4C)

- Chunks of rocks come in many sizes and shapes, from boulders to grains of sand and even smaller.
- Change is something that happens to many things.

The Structure of Matter (Benchmark 4D)

- Objects can be described in terms of the materials they are made of and their physical properties (color, size, shape, weight, texture, etc.).

Our decision to incorporate children's ideas into the design of activity series stems from literature on the role children's prior knowledge plays in learning science concepts, and our desire to help children construct understandings about the wide variations there are in rocks and how rocks are formed (rather than just memorize facts about rocks). Over the past 20 years, a growing body of literature has documented the ways in which children's prior ideas influence their science learning. Widely accepted conclusions of conceptual change research include (a) children do not enter science classrooms as blank slates, but with experience-grounded views about how the world works; (b) these ideas often conflict with the knowledge claims of science that children are expected to study and learn; (c) these ideas are highly resistant to change by traditional instructional approaches; and (d) when instruction succeeds in changing student's ideas, the changes induced are sometimes quite different than those intended

(Champagne, Klopfer, & Gunstone, 1982). [1] A number of conceptual change teaching models have emerged from this research, and share a common view of stressing the centrality of children's ideas in classroom activity, discussion, and exploration.

To this end, teachers seeking to help their children to express, discuss, evaluate, and ultimately revise their understandings of science concepts have a wide body of research literature on children's conceptions to draw upon. However, as is the case with some domains of science, we found very little research on children's understanding of how rocks are formed. In a study of the way children classified rocks and minerals, Happs (1982) concluded that young children were not aware that all natural aggregations of minerals are rocks. Further, children thought that rocks polished by people were no longer "natural" and thus, could not be rocks. This led us to consider doing a pre-assessment to find out what our children thought about rocks.

Our basic assumption in designing our activity series was that while children's prior ideas ought to be central to activity and discussion, we also needed to consider ways to foster a classroom of interested, motivated, and thoughtful learners. Shapiro (1989) discusses ways teachers can use a pre-assessment to develop classroom profiles which make explicit and public the diversity of children's ideas. To construct a classroom profile, the teacher asks children to respond to several open-ended questions about a science concept, then collects, reviews, and categorizes the responses. The teacher then posts the categorized profile on an easel pad or chalkboard, with or without student's names. Cosgrove and Osborne (1985) refer to the pre-assessment of children's views as the preliminary stage of their generative learning model of science teaching.

We felt that the profile/preliminary stage assessment could provide a source of information to guide instructional design. Specifically, we gave a written pre-assessment to children to get a better sense of the diversity and nature of their ideas about rocks and how rocks are formed. We followed up the written pre-assessment by interviewing ten children from each class. A sample of a written pre-assessment is shown in Figure 7.1. Examples of children's responses are italicized.

Some results of our pre-assessment did not surprise us. For example, pre-instruction interviews revealed that children had limited ideas about rocks. They thought that rocks must be a certain size, texture, color and shape, rather than being any natural aggregation or combination of one or more minerals. Student's responses indicated that they were somewhat unclear about what could be called a rock. For each of the four sample rocks shown to children, at least some (a range of more than half the class to three students) claimed that the sample was not a rock. This finding corresponded to those of Happs (1982). The children used a variety of reasons for their classifications, including too big, too small, too smooth, and wrong color. We could not see a pattern of classification. Concerning whether or not the rock would look the same inside, about 90% of the children thought that rocks would look different inside.

We were quite surprised, however, when we analyzed children's responses to the questions about how rocks got to the places they were found and how rocks were made. We discovered that a number of children thought that people make at least some kinds of rocks, and that people have a lot to do with where rocks are found. For example, a large percentage of children thought people were the primary agents for transporting rocks (75% for rocks on their playground, which was largely a "natural area," and 49% for rocks found in the creek). Even

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[1] For those interested in a readable and informative introduction for classroom teachers, we recommend *Learning in Science: The Implications of Children's Science*, by R. Osborne and Peter Freyberg (1985). Heinemann.

1. **Which of these would you call a rock? [Note. All samples were rocks.]**
    Sample A **Do you think this is a rock? Yes No**
    Why? *Because it is big and it looks like one.*
    Sample B **Do you think this is a rock? Yes No**
    Why? *Because it looks like a real rock.*
    Sample C **Do you think this is a rock? Yes No**
    Why? *-It doesn't look like one.*
    -Its color - most rocks don't look like that.
2. **If you had magic glasses and could look inside rocks, do you think they would all look the same? (Please circle your answer and explain.)**
    Yes, I think they would all look alike because...
    No, I think they would not all look alike because...
    -they all look different on the outside.
    -they probably look different all the way through.
3. **This rock was found in a creek. How do you think it got there?**
    -Hailstorm.
    -When someone was fishing they brought it there.
4. **How do you think rocks are made?**
    -From dino prints. You can see dino prints in rocks. They step on it or sit on it (the ground, which is dirt).
    -People put dirt and water in machines to make rocks.
5. **Do you think rocks could be alive? (please circle your answer and explain.)**
    Yes, I think they are alive because...
    No, I think they are not alive because you could see it: it would drink water like a plant and grow a little.
6. **What would you like to learn about rocks?**
    -If they were around for 2,000 years.
    -I would like to know how old they are.
    -I would like to know how they are made.

Figure 7.1 *The written pre-assessment given to children during our planning stage*

more striking was the number of children who thought that rocks were made by people (about 40%). This differed from what Happs (1982) reported in a study of New Zealand children. Our children's responses included: (a) rocks are made from cement (or from rain, water, and mud); (b) rocks are made from little pieces, like seeds, and they grow; (c) rocks are made by people in a machine behind the local grocery store; and (d) rocks are made from liquid dye machines.

Learning that a number of children believed people to be largely responsible for making rocks and transporting them led us to abandon our initial plan of developing the unit around a commercially-available curriculum package. In that curriculum, teachers and children explore how rocks are formed by analyzing teacher-made "mock rocks." Because we felt this might reinforce children's ideas that rocks were made by people, we decided to search for materials which would help the children to understand that rocks are natural materials in the sense that

Earth's crustal layers are made of rock and that rocks are made in nature from materials such as lava or sediments (e.g., sand, gravel, and shells). We then sought ways to integrate audiovisual materials, children's literature, and observing rocks into the activity series, rather than the "direct experience" of taking apart teacher-made rocks. To our disadvantage, the school sits in a cornfield on the coastal plain. Thus, there were no volcanic materials, cliffs, caves, or huge boulders available nearby for children to examine and study. As discussed in the next section, we decided to have children collect a special rock of their own and make observations on an assortment of rocks to help them develop their observation skills and become aware of the wide variations in rocks. We would also integrate information from books, videotapes, and videodiscs along with direct experiences with igneous and sedimentary rocks to help the children understand that rocks are naturally occurring materials which come from the Earth.

The 'Special Rocks' Activity Series

In this section, we outline the activity series we designed. Science content standards are targeted throughout the activity series by providing opportunities for children to develop their observational and analytical skills in a collaborative and constructive manner. Week one emphasizes observing and communicating about the variation in rocks through developing the skills of giving accurate, complete descriptions orally, in writing, and through mathematical representations (e.g., graphs), and making observations (sight, touch, smell, hearing, and measuring size and mass). Measures of size and mass are used to develop mathematical ways of making comparisons—such as making pictographs and bar graphs of the relationship between size and weight of rocks. Importantly, the rocks in question are those collected by children at the start of the unit (hence, the title "special rocks"). Week two emphasizes rocks as naturally occurring parts of the Earth that are transported and changed by water, wind, and ice. Emphasis is placed upon considering the various ways that rocks form naturally (inside of the Earth, volcanoes, and sediments), and how rocks are moved from one place to another by natural processes.

The following outline shows brief daily lesson plan summaries for the entire activity series. These summaries include the title (specifies the objective of the lesson), questions for teachers to pose, descriptions of small group and whole class activity/discussions (meetings), materials and resources used, and homework.

Week One

Day 1: How to Find your Special Rock

READ TO CLASS: *Everybody Needs a Rock* by Byrd Baylor, which provides a charming description of ten "rules" for selecting your own special rock, and the first pages of *The Magic School Bus Inside the Earth* by Joanna Cole.

HOMEWORK: Find your special rock out-of-doors. Each child gets a paper bag for his/her rock and a card with two questions to think about: Where did you find your rock? How do you think it got there?

SMALL GROUPS: Write in logs—where will you look for your rock? What type of rock do you think you will look for?

MATERIALS: Paper lunch bag for each child, card with questions.

Day 2: Observing and Describing your Special Rocks

MEETING: (rocks remain in bags). Have children discuss where they found their special rocks and how they think they got there. Discuss how rocks might be described—shape, texture, color, size (e.g., "about the size of a ______"). Model how to describe rocks using the teacher's special rock. Write the description on the board. Explain that the goal is to write a good description so that someone else could find the rock by reading it.

SMALL GROUPS: On an index card, each child writes a description of her/his rock and name on the opposite side (children can ask members of their group for help but should keep rock hidden from the rest of the class). Teacher places rocks of half the groups in the center of the room and gives card to each child in other half of groups. [Note: Children stay in groups until the cards are given out, then move to one side of the meeting "circle."] Teacher asks children to read descriptions they are given and look over rocks in center of the floor. Teacher asks three or four children who think they know which rock is described on their cards to point out the rock and check with the potential "owner" of the rock. After a few have located the correct rocks, the teacher has the rest locate the rocks described on their cards. After all rocks are accounted for, put out rocks from the rest of the group and give the other half descriptions and proceed as above.

MEETING: Discuss what made it easy or hard to match rock with description, especially which words made it helpful.

LOGS: Respond to questions: Where did you find your rock? How do you think it got there? If you would like to explain why you chose it, please do. Tape card with description on the next page of the log.

MATERIALS: Each student's special rock, index cards, tape.

Day 3: Making More Observations: Touch

MEETING: (1) Have all children put rocks in front of them. Add some different types of rocks (e.g., bigger, different colors). Have children notice all the different types and explain that scientists would call them all rocks; (2) Discuss other ways to describe rocks (besides visually). Touch—Discuss how children might recognize their own rocks if they couldn't see them. Close eyes and feel rocks. Discuss what's special about their rocks.

Divide children into two groups—stand or sit in circles. Practice passing rocks behind them. Begin—When teacher says "pass rocks" children pass rocks behind backs to next person so rocks cannot be seen. When children believe they have their own rocks they check and, if it is theirs, move out of circle. When all children have their own rocks, discuss how they knew which rocks were theirs. Discuss how rocks might have gotten their shape or texture.

LOGS: Write ideas about the above, e.g., what made it easy or hard to identify a rock by touch.

MATERIALS: Each child's special rock.

Day 4: Making More Observations: Smell, listen, "change" (wet)

MEETING: Ask what other observations could you make about rocks?

Smell—demonstrate how to smell "scientifically"—waving odor to nose with hand. Smell own rock and neighbor's rock. If available, pass around the mineral sulfur and/or other unusual smelling rocks, such as bituminous coal or oil shale. Think of ways to describe smell. Discuss why they might smell alike or different. Listen—to rock as you roll it in your hand, on the floor, etc. Compare with your neighbor's rock.

Discuss with children whether they think rocks will smell or look different or the same when wet. Discuss why it would not be a good idea to taste rocks [not sure where they have been; and other safety issues]. Explain that geologists, however, do sometimes taste rocks.

SMALL GROUP: Use hand lenses to look at rocks. Describe in log. Wet rock, smell, look at—describe in log.

MEETING: Reporters report on interesting happenings in their groups. Discuss any other ways to observe/describe rocks.

MATERIALS: Own special rocks, sulfur (mineral) or bituminous coal, hand lenses, tub of water for each group.

Day 5: Making More Observations: Measure

MEETING: Discuss other ways to describe rock, e.g., measurement.

Demonstrate how to use balance to find mass and the tape measure to find length, width, and circumference. Predict whether certain rocks will have greater or smaller mass than rock teacher weighed.

SMALL GROUPS: Each child weighs and measures rock,traces rock on paper, cuts out the tracing, and labels the cut out with his/her initials and mass of rock in grams.

MEETING: Make a pictograph by placing rock cutouts at the correct position on a large poster paper that has a horizontal line along the bottom labeled with categories for mass (e.g., 0-30 g., 31-60 g., etc.). Discuss relationships of size and mass [generally, the larger the rock, the larger the mass]. Introduce "trick" rocks i.e., larger piece of pumice and smaller (heavy) metal ore samples and find mass and/or compare mass by placing on opposite sides of balance.

LOGS: Transpose pictograph to bar graph.

MATERIALS: Each child's special rocks, "trick rocks" (ores, pumice), tape measures, scales, standard unit masses, large poster paper for class graph, bar graph paper for log.

Optional day: More grouping

MEETING: Discuss other ways rocks might be grouped.

SMALL GROUPS: Group rocks in various ways. Be able to explain grouping system. Emphasize that they are all called rocks by scientists.

MEETING: Explain grouping. Children could also graph rocks to show grouping.

Week Two

Day 6: The Inside of the Earth

MEETING: What do you think the inside of the Earth is like? Have children brainstorm and explain their ideas. Write them on the board. Read *The Magic School Bus Inside the Earth* by Joanna Cole and/or view first part of video *What's Inside the Earth?* by Rainbow Educational Media. Review brainstorming ideas for "best fit" to scientists' ideas. Show model of the inside of the Earth. Compare layers to the picture on the story. Emphasize that inside of the Earth is solid or molten ores—there are no oceans, tunnels, etc. [2]

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[2] During the first teaching of this lesson the Northridge Earthquake occurred in the Los Angeles area, so we did a mini-lesson on tectonic plates riding on the mantle, the San Andreas fault, and how plates slide past one another and cause earthquakes.

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SMALL GROUPS: Provide "puzzle pieces"—four layers of inside of the Earth (See Figure 7.2). Each child colors in and labels one of the four layers (crust, mantle, outer core, and inner core) with name, size, type material. Children put layers (puzzle) together as a poster with members of their group.

LOGS: Draw cross-section of the Earth and label.

MEETING: Review posters. Think about how scientists might know this.

MINI-LESSON: How do we know about inside of Earth? (booklet by researcher).

MATERIALS: "Puzzle pieces" layers of the Earth, labels/post-its, model of inside of Earth, book: *The Magic School Bus Inside the Earth*, video: *What's Inside the Earth?*

Day 7: Volcanoes and Igneous Rocks

MEETING: Show some igneous rocks. "Here are some rocks made of the same stuff as inside of Earth. How do you think they got to the surface?" Discuss and predict. Show section on igneous rocks from *What's Inside the Earth?* video.

SMALL GROUP: Make observations on igneous rocks: lava rock (scoria), obsidian, pumice, basalt, granite, etc. (wet, smell, feel, weight, etc.).

LOGS: Enter descriptions, pictures of what volcano might have looked like.

MEETING: Discuss differences in size of holes, etc., how they might have been formed. Ask, "Do you think all rocks are made this way?" Think about classmates' special rocks or ones in the room. [Read aloud from tradebooks on volcanoes.]

MATERIALS: Video: *What's Inside the Earth?*, igneous rock samples: obsidian, pumice, granite, basalt, and scoria, scales, standard unit masses, tub of water. [3]

Day 8: Sedimentary Rock

MEETING: Show black sand made from volcanic rock; explain it came from a beach a few miles from a volcano; ask where it might have come from. Show some red sand and beach sand. "Could this material ever go together to make a rock?" Look at sedimentary rock section of videodisc *Windows on Science* or sections on National Geographic Society video *Every Stone has a Story*. Notice cycle of sand, soil, etc. to rock and rock to sand and soil.

SMALL GROUPS: Provide children with small plastic boxes (e.g., "bug boxes") containing sediments and samples of sedimentary rocks formed from the sediments. Have the children work together to decide how to match the sediment and rocks. For example use: reddish-orange sand and reddish-orange sandstone [4]; white sand and white sandstone (nearly pure quartz sandstone); pieces of shells and fossiliferous limestone or coquina; clay-rich soil and shale. Children may need to use rock identification books to help them with close matches (e.g., to determine which rock would have been formed from quartz sand or shells).

LOGS: Children explain their matches.

MEETING: Discuss decisions.

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[3] A diversity of rock samples can be obtained rather inexpensively through vendors of science supplies. Alternatively, instructors at university geology departments are often willing to donate rock specimens to teachers.

[4] Iron oxide gives this sandstone its color; the iron oxide is the cement between the sand grains.

MATERIALS: In small clear plastic boxes: sediments e.g., clear/white ("pure") quartz sand, reddish (iron-stained) quartz sand, clay-rich (very fine-grained) soil, and shells. Pasted on cards: red sandstone, white sandstone, shale, and fossiliferous limestone or coquina.

Day 9: Rocks? or Not?

MEETING: Show children several different kinds of rocks and "non-rocks" (i.e., things some children think of as rocks, but are actually pieces of concrete, asphalt, or brick). Ask children to explain which they think are rocks and which are not rocks. Explain that scientists define rocks as natural combinations of minerals; that is, rocks are not made by people. Show them a chunk of concrete and the ingredients people use to make it: small rocks, powdered limestone, and sand (we obtained these from a nearby concrete plant). Show pictures of a concrete plant and cement trucks. Explain that even though the ingredients of concrete are found in nature, concrete is not considered a rock because people had to find and mix the different ingredients to make it. A good tradebook resource to read aloud to children is *What is Rock?* by Fred and Jeanne Biddulph.

SMALL GROUPS: Provide a variety of rocks and "non-rocks" (pieces of concrete, asphalt, and bricks). Have children group them under the labels "rocks" and "not rocks."

MEETING: Have children explain their decisions.

MATERIALS: A variety of rocks (different sizes, shapes, textures, and colors); a collection of people-made materials which are sometimes mistaken for rocks (e.g., pieces of concrete, cement, asphalt, bricks); ingredients of concrete (small rocks, powdered limestone, and sand); pictures of concrete plant and trucks; large labels—rocks, not rocks; book *What is Rock?*

Day 10: Sedimentary Rocks and Sediment: Erosion

CONCEPTS: Rocks are uncovered and/or transported by streams, wind, etc.; large rocks break into smaller rocks.

Visit stream; make predictions about what will happen to small rocks, soil placed in stream, what changes there might be in the stream; revisit the stream during the year. Look for signs of erosion and what happens to soil and rocks. Investigate ways large rocks are broken. Take pictures, videotape. Make the stream field trip several days later (preferably after a rainstorm).

MEETING: What do you think you might see at the stream? Look at sections of *Windows on Science* videodisc on erosion.

GROUPS: Visit stream and look for erosion and rocks. How did they get there? Will they move?

LOGS: Draw pictures of stream and write predictions. Visit stream several more times during year to look for changes.

Day 11: "Making" Sedimentary Layers

MEETING: If clay, sand, etc. are mixed with water together in a jar, what will happen? Small groups, set up jars; predict.

LOGS: Draw and make predictions about what will happen. Several days later, meet to discuss results. Could layers like this turn into rock? What kinds of rock? Look at portions of *Windows on Science* videodisc featuring rock layers. If possible, visit areas where rock layers can be seen.

An important feature of our activity series is the use of resources to help children develop knowledge and skills, and to understand similarities and differences between rocks and things made by people (concrete), and between the activity of children and the activity of scientists. These resources included children's science books, videotapes, a visit from a professional geologist, and a visit to a concrete plant. The geologist focused on the similarities between the observations the children had made and recorded and what geologists do. Since a number of children thought that rocks were made by people, particularly that rocks were pieces of concrete or pieces of the road, the materials gathered during a visit to the concrete plant and used in the lesson on rocks and non-rocks were essential in showing children that concrete was not a rock by scientists' definition.

Reflections

This section of the chapter includes the personal reflections of the three teachers who wrote and taught the activity series and the university faculty who collaborated with them. The teachers (Fredricks, Cain, and Wilson) focus on features of designing and teaching process, such as the importance of collaborating with others and the ways in which the activity series differed from other types of instructional approaches. The researchers (Wier and Smith) discuss the effectiveness of the unit in helping children to learn about rocks and how they form, and the importance of connecting children's activity to outside resources, such as the visit with the professional scientist.

Karen H. Fredricks—Using Children's Thinking to Guide Planning

I am not a geologist; I have been an elementary teacher for 17 years and currently teach third grade. My colleague and I collaborated with a researcher and her graduate students to prepare our unit. Together, we compiled several questions to be used as a pre- and post-evaluation tool. The pre-evaluation and the subsequent interviews with our children enabled my colleagues and I to discover the variety of naive conceptions our children held about the formation and composition of rocks. For example, when showing children several different rock samples (see Figure 1), we found that they did not agree that each sample was a rock. Some children ruled out a sample because it had sparkles and it looked like a mineral. Some ruled it out because of its size, weight, color, shape, lack of smoothness, or because it looked like a crystal. When we asked children to explain how they thought rocks were made, their responses included: they were made by people from "black top," charcoal, and science stuff; from the Earth, the hard ground, and the Sun; somebody made them out of bricks or paper. In response to the question "How long do you think it takes to make a rock?", children replied: "little ones probably an hour, and big ones about three hours," "about four days," "1,000 years," and "about a half an hour." Several children thought that rocks were alive. Furthermore, we found from the interviews that many of these third graders did not understand that rocks were naturally occurring objects.

Gathering, analyzing, and discussing this pre-assessment was vital to our planning and enabled us to develop the *Special Rocks* activity series. Collaboration featured brainstorming sessions between teachers and researchers where we shared and built upon each others' ideas in an effort to base the unit entirely upon what the children understood and did not understand about rocks. Our discussions prompted us to drop our original plan (having children perform scratch tests and streak tests to identify the mineral contents of their rocks) and create an activity series that would engage children in observing a variety of rocks and determining how rocks are made. As a classroom teacher, I realize that finding the time to do a pre-evaluation before each unit is often difficult, if not impossible. However, this experience convinced me that my students could benefit from the extra insight I gained from the pre-assessment, and that I should try to conduct one prior to teaching a unit I have never taught before.

Karen Fredricks—Implementing a New Lesson Structure

In terms of structuring the lessons, we developed and implemented a format that we had not used before. The first 20 minutes was with the entire class sitting in a circle on the floor. This involved a short mini-lesson in which I reviewed the concepts previously learned and elicited children's ideas about the concept for the day. I then divided the class into small groups of four children each, where they touched, measured, traced, graphed, and then recorded their findings in their science logs. This small group session lasted for about 30 minutes. This gave me an opportunity to circulate among the groups, monitor their progress, and gain insights into their discoveries that I otherwise would have been unable to do. Finally, for the last ten minutes, the children came to the circle on the floor to discuss their group and individual findings, and to read parts of their science logs. This enabled children to clarify their observations and share any exciting insights.

At the end of each lesson, I asked questions to start children thinking about the upcoming topic. This kept their interest level and involvement outside of science class very high. I had them maintain science logs of their findings and I encouraged accurate and complete descriptions (written and oral) of what they did and observed. I also searched for books and literature to enhance the activity series.

The *Special Rocks* activity series was exciting and enjoyable for me and my students. The combination of children's literature, hands-on exploration, making observations, and discussing our findings kept my children involved and on task. They signed out library books on rocks, the Earth, and volcanoes, spent their recess time looking for rocks and sharing them with each other, and came up with questions and began to look for the answers on their own. I noticed a high level of interest and involvement, and improved cooperation and behavior. The children did not want science time or the unit to end.

Betty-Jane Cain—The Collaboration Process

My colleagues and I have collaborated with Dr. Betty Wier since Thurgood Marshall first opened its doors in September 1993. In our collaboration, groups of teachers attended monthly meetings to develop and discuss the constructivist paradigm for teaching science, and to develop several workable units, including a kindergarten/ first grade unit on lights and shadows and second grade unit on magnets. As third grade teachers, we needed to develop a unit that was consistent with our district's curriculum for third grade. For several reasons, we eventually decided on a rock unit. It could address our district's requirements and new state standards. It could be an activity-based unit and could be conducted in classroom centers as well as the science lab format. Lastly, and not to be overlooked, children love rocks! We knew that we would have very little difficulty motivating children to find their own special rocks.

One of the first differences in this new science model was that teachers would be involved with the planning of the unit from its inception. This also meant that we were given two half-days to plan and discuss the unit. Substitutes were paid for with an Eisenhower, Title II grant. During first meeting, we decided upon the pre-assessment questions we would ask children about rocks. We also planned the first week of the unit and decided to use the FOSS Kit on rocks for the second week. Our first meeting lasted about four hours, portions of which were quite intense as we discussed and debated the concepts to be taught and learned. However, we were treated professionally; we were on equal footing with our university counterparts; and our opinions were listened to and valued. In the end, teachers and researchers reached a consensus about target concepts and outcomes for the unit.

Our collaborative team met again one month later. By then, we had given our written pre-assessment and interviews. It was evident to us all that these children had little idea about what rocks were. Some thought rocks were made by people and one of my students thought they were made in a machine behind a local supermarket! Armed with this new information about our children's understanding, we eliminated the FOSS Kit from our second week of instruction so as to not reinforce some children's naive conception that rocks were made by people.

The collaboration process benefited colleagues throughout the school. The first two years we implemented the Special Rocks unit in the University of Delaware Science Lab within our school and with the help of the staff and regular debriefings. This year other classes have been visiting the Science Lab and we have implemented the unit in a classroom setting. However, we do not feel cut off because we know that our colleagues at the University are only an e-mail away. As a teacher, the collaboration with the university has been a life-changing event. I now understand the need for preassessing children's conceptual understanding prior to developing a unit. I have also learned the value of collaboration and the need for ample time in planning for a unit. Having the university as a resource was a tremendous strength in administering preassessments, and in developing and implementing the activity series. Finally, this collaboration eventually led to our presentation of the unit at the 1995 NSTA national convention in Philadelphia. It was well-received and we felt empowered. This was "heady stuff" for primary grade teachers!

Sharon Wilson—Implementing 'Special Rocks' in a Classroom Setting

When I first discovered I would be able to teach the rock unit, my initial reaction was "How am I going to do that?" I had little knowledge of the topic and no materials. Luckily I was asked to participate in the science lab at my school and used a sequence of lessons developed by my colleagues. Each lesson ran between 30-45 minutes and the unit lasted several weeks. You might be thinking "that sounds great, but my school doesn't have a science lab." No need to worry. This year, I used the lessons in my own classroom and I would like to share with you how it can be done.

Your main challenge may be gathering some of the needed materials (specific rocks, magnifying glasses, and balance scales), but this is worthwhile because they are reusable year after year. You may be able to find a school or outside source of funds that will help with the expenses. Other than that, the science journals are easily made and the literature/books used may be found at your school or local library.

I enjoyed teaching the rock unit because it enhanced my children's skills in different areas while their knowledge and enthusiasm about rocks grew. Some of the main benefits I experienced were:

1. Sharing literature about rocks initiated interesting discussions and questions. Also, children began to read about rocks on their own time!
2. The children enjoyed using the science journals since their writing was inspired by their previous observations and activities (see examples).
3. The hands-on activities (which were not difficult or time consuming to set up) helped the children to stay focused through their lessons and led to rich discussions about the things they discovered. This was a major difference compared to using worksheets from an activity book.
4. Using outside resources enhanced the unit. For instance, when a geologist came for a visit my students were exposed to additional information about rocks and the responsibilities of a geologist. This can be easily arranged by contacting your local college or university.

This unit was a worthwhile experience which helped me to share information about rocks with my students. It proved to me that teaching and learning science can be fun and exciting.

Betty Wier—Accomplishing the conceptual goals of the unit

A primary goal of the unit was to give the children opportunities to use their senses to make observations about the natural world and to practice giving accurate and complete descriptions orally and in writing. Another important goal stated by the teachers who helped develop the unit was to pique and sustain children's natural interest in rocks.

We felt that the children's experiences with observing their special rocks and having to provide descriptions so that others could recognize their rocks provided good practice and good reasons for observing and describing accurately. But we also felt it was only a beginning—they need more opportunities to sharpen these skills. As far as sustaining the children's interest in rocks, the teachers reported that children continued to collect and share rocks after the conclusion of the unit.

We addressed several concepts in the unit. First, we wanted children to understand that rocks come in many shapes and sizes, from boulders to grains of sand. We also wanted to help children understand that rocks were *natural* aggregations of one or more kinds of minerals. During the lessons, we pointed out that all the special rocks were indeed rocks, though of many shapes and sizes. In addition, we had a variety of rocks on display which varied even more in appearance. Our post-assessment (given several weeks after the conclusion of the unit) showed an improvement in children's understanding about which samples should be called rocks. In particular, there was a significant gain in children's understanding that a rock as small as a pebble could be a rock.

The second week of the unit focused on how rocks are made. We saw a major improvement of children's ideas about how rocks are made. Roughly 54% of the children moved toward a scientific conception of rocks being made by natural processes. Only 7% of the children continued to cling to the idea that people had something to do with making rocks. We believe that the incorporation of materials from a local concrete plant into the lessons, where children got to see photographs of how concrete was made and the materials from which it is made, helped children to realize that there is a difference between rocks (as naturally-made Earth materials) versus objects made by people (e.g., concrete, brick, and asphalt).

Michael Smith–Having Scientists Visit the Classroom

Aware of my background as a professional geologist, Betty Wier invited me to visit the classrooms of the three teachers as they implemented the Special Rocks unit. In particular, I was asked to have a conversation with children about how geologists collect and investigate rock samples. My goal was not to simply describe how geologists observe rocks, record these observations and ideas in their notebooks, and discuss/share their work with other geologists, but to also emphasize how this was just like what the children were doing. When I came into the classroom, I sat down in a circle with the children and asked them about what they had been doing that week. As each child offered an idea, I wrote it down on a easel pad. After about five minutes, I had listed about 20 things! Examples of the children's responses include: collected a rock, felt how hard it was, weighed it, looked at it when it was wet versus dry, wrote down my observations, shared my results with my group and so on. I then talked about what I do when I go out to study rocks. Each time I described something, I made a small check mark next to a child's response. By the time I had described each observation, test, and process, I had pretty much checked all of the children's responses. I think this helped children to realize that their work in the science classroom was very similar to the kinds of things that scientists do when they study rocks.

In a second visit to the classroom during week two of the unit, I served as "geological consultant" to the children, helping them to better understand where their special rocks came from. I met children in small groups or teams. As we sat on the floor, each child gave me his or her special rock and asked me to name the rock and tell me where it came from. In all cases, I let children know that they had indeed collected a rock. I talked them through the process of observing and testing each special rock, and I recorded some notes for them on an index card. For example, when a child handed me an intrusive igneous rock (e.g., gabbro or granite), I described how the appearance of the crystals (color, size, shape) helped me to draw conclusions about how the rock had formed and what kinds of minerals it was made of. In some cases, I was a bit perplexed about what I would call the rock, so I took the opportunity to talk about additional tests I might do in a lab or how I might ask another geologist for his or her opinion about what it might be.

Overall, the children really enjoyed knowing more about where their rock came from. About a week after I visited the class, I received a package of personal thank-you notes from the children, beautifully decorated with diagrams and drawings of their special rocks. Several children announced their intent to become geologists!

Conclusion

The Special Rocks unit takes advantage of children's natural curiosity about rocks to address national science content standards/benchmarks—developing abilities to do scientific inquiry and learning about the Earth's materials. Development of the unit was enhanced by the collaborative efforts of elementary teachers, university science educators, and a geologist. Their combined efforts and expertise which included understanding children's interests, abilities and ideas about rocks, and understanding of rocks strengthened the unit. It is our hope that sharing our experiences collaborating, developing, and implementing this activity series motivates others to consider ways they can work together to provide exciting and interesting learning experiences in math and science for their children.

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Chapter 8

Stars and Constellations in the Classroom

Nancy R. Lebofsky & Larry A. Lebofsky

In a recent issue of *Science and Children* magazine, editor Joan Braunagel McShane (1996) described the preschool or kindergarten learner as "a scientist waiting to happen." Young children are excellent questioners, observers, and explorers with boundless curiosity about the world around them. One fascinating and mysterious part of this world is the sky. Recent presentations to second and third graders drew questions as varied as, "How did the Sun get so hot?" and "Has a star ever fallen from the Big Dipper?" While these very young learners are obviously not ready for the physics and mathematics usually associated with astronomy, they can begin to apply concepts they are currently learning to the twinkling little stars they often sing about.

Since 1990, we have worked with teachers from grades K-8 in a teacher enhancement program called Project ARTIST (Astronomy-Related Teacher Inservice Training) and a K-5 program called Project ACCESS! (All Children Can Explore the Solar System!). Primary grade teachers have taken the scientific content delivered via these programs and have either modified the projects' activities or created their own activities based on their classroom experience to provide astronomy instruction for young learners. Integrating a high-interest science topic with mathematics, reading, language arts, social studies, and fine arts instruction not only allows the students to learn some very basic astronomy, but nurtures an appreciation for the sky, as well as providing opportunities to reinforce mathematics, reading, and writing skills.

This chapter offers classroom tested suggestions for incorporating and integrating astronomy into the primary grade curriculum. Size, shape, and color can be used to sort and describe stars in a rudimentary way. Star "life cycles" can be added to other life cycle studies. Pattern recognition and graphing skills can be utilized in the study of stars and constellations. Finally, as a supplement or extension to the actual science lesson, literature based activities can help reinforce constellation patterns, constellation names, and our location within the Milky Way galaxy, as well as providing multicultural interpretations of the star patterns in the sky.

Size, Shape, Color

If you ask a young student to draw a picture of a summer day, the common representation of the Sun is a circle in the sky, colored yellow. Children already "know" two properties of the Sun: it looks "round" and it is yellow in color. Their drawings incorporate two properties of all stars: they have a specific shape (a circle when drawn on paper) and they have a color, one of which is yellow. The piece of information which they may lack is that our Sun is, in fact, a star.

Comparing and contrasting sizes, colors, and shapes of objects is very likely already a part of the young learner's classroom experience. Making the connection that stars also have sizes, colors, and shapes is a rudimentary, but important, beginning in their study of stars and constellations. Making the distinction between the five-pointed red or gold or green star which the teacher may affix to an outstanding assignment (an artist's star) with the spherical object in space (a scientific star) can defuse misconceptions. This is why we prefer to represent the three-dimensional spherical star as a circle on two-dimensional surfaces.

Construction paper circles cut to the appropriate proportions can be used to introduce the colors and sizes of stars, as well as the vocabulary which scientists use to describe stars. The circles also reinforce the proper shape of a scientific star. For use on a bulletin board display, try using actual proportions, as presented in Figure 1 (Braus, 1989). For hands-on use (and for storage and transportation purposes), we use circles of diameters from the half size column. Please note that this is a simplified chart; stars also come in other designations such as orange, red-orange, blue-white, subgiant, etc.

Styrofoam, sponge, or rubber balls (spheres) can also be used, in appropriate sizes, to reinforce these three concepts about stars. To convert the diameters in Figure 1 into circumferences, multiply the diameter by π (3.14); e.g., a 30 cm diameter circle would require a 94.2 cm ball. Exact diameters are not critical, as stars come in a range of sizes within each category. For example, use a basketball to represent a red supergiant, a sports ball for a blue giant, a golf ball or ping pong ball painted red for the red dwarf, and a marble for the white dwarf.

Additional Concepts and Vocabulary

Using either the paper circles or spheres allows review or reinforcement of the concepts of small/smaller/smallest and big/bigger/biggest. While the 27.5 cm diameter blue giant star looks very big compared to the 12.5 cm yellow star, the 60 cm diameter blue supergiant is even bigger. Using a familiar story such as Jack and the Beanstalk to compare a boy to a giant (e.g., our Sun to a star such as Rigel in Orion or Deneb in the Northern Cross) may add more meaning to these star classifications. The students can then create a "supergiant" of their own. Using pictures from a seed catalogue of a dwarf fruit tree and a standard fruit tree can illustrate the difference between a medium star, such as our Sun, and a dwarf star.

	Diameter*		**Half-Size***		
Star Type	In.	cm.	In.	cm.	Example
Red supergiant	24	61	12	30	Betelgeuse
Blue supergiant	18	46	9	23	Rigel
Red giant	15	38	7.5	19	Aldebaran
Blue giant	11	28	5.5	14	Mintaka
Yellow medium	5	12.5	2.5	6	Sun
Red dwarf	3	7.5	1.5	4	Barnard's Star
White dwarf	2	5	1	2.5	Sirius B

* in = inches, cm = centimeters

Figure 8.1 *Star sizes and colors*

Mathematics Application

A simple graphing and predicting activity can also be used to integrate information about star colors with the mathematics lesson. Using a large star-shaped paper punch (an artist's star!) or a circle pattern (e.g., a soda bottle cap), punch or cut stars from red, blue, white, yellow, and orange construction paper. Place the stars in a plastic baggie or paper bag. Provide a blank graph with large squares for each student. Working with a small group of students, allow each one to reach into the bag and pull out a "pinch" of stars. Ask the students to make predictions. Which color star will fill the most blocks on the graph? Which color star will fill the least? Ask the students to place their stars on the graph, sorting by color. If you have discussed the relationship of a star's color to its temperature with older students, they can graph the hottest stars (white) in the first row or column, followed by the next hottest (blue), medium (yellow), cooler (orange), and coolest (red) stars.

Life Cycles of Stars

Cycles are often a part of the elementary science curriculum, e.g., the water cycle, life cycle of insects, plants. Stars also have life cycles, varying according to the type of star. Teachers from both our ACCESS! and ARTIST projects have successfully incorporated star life cycles from kindergarten through middle school, including special education classes.

It is very important to reassure young students that stars live for a very long time; our own Sun will continue to shine for billions of years. Some teachers prefer to use Life Cycle, instead of Birth and Death of a Star, to alleviate any fears the children may have about the eventual demise of our Sun.

We have used a modified version of a Birth and Death of a Star activity (Braus, 1989) in several of our teacher workshops. Dimming the lights while playing appropriate background music adds a dramatic touch to the descriptions provided, which traces the life of a red giant star from nebula through black dwarf. Once students are comfortable with the concept of cycles, and once they are familiar with some astronomy vocabulary (e.g., red giant, white dwarf), they are eager to apply their imaginations and artistic abilities to the creation of multimedia bulletin boards, mobiles, big books, accordion books, songs, and other projects which illustrate the changes a star experiences during its cycle.

Students as young as kindergarten have created extraordinary bulletin board displays illustrating the stages of stars. Figure 8.2 presents information to allow students to choose from one of several life cycles for their project. Small, medium, and large refer to the stars' masses. The small stars burn for billions of years; the medium stars, such as our Sun, burn for about 10 billion years, and the larger stars burn for a few million years.

For younger students, try choosing one cycle to study and illustrate. Even primary grade students seem to be fascinated with black holes. While few adults are comfortable with the physics of black holes, a creative kindergarten student finished off a star cycle bulletin board display by stitching black yarn over and over a piece of burlap to represent a black hole! Mobiles, posters, and accordion books have also been used to illustrate star cycles.

Constellations

Constellations are simply patterns of stars, as viewed from our perspective on Earth. We use a variety of activities to allow young observers to begin to recognize common star patterns. If you are fortunate enough to live in an area with fairly dark skies, scheduling an observing night with local amateur or professional astronomers will provide an exciting experience for your students. Tips for scheduling an observing night have been published by a Project ARTIST facilitator in Science Scope (Cañizo, 1995). Some important considerations include phases of

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Types of Stars

STAGE	SMALL STARS	MEDIUM	LARGER	LARGEST
1	nebula	nebula	nebula	nebula
2	protostar	protostar	protostar	protostar
3	red dwarf	yellow star	blue giant	blue giant
4	red giant	red giant	red supergiant	red supergiant
5	white dwarf	white dwarf	supernova	supernova
6	black dwarf	black dwarf	neutron star	black hole

Figure 8.2 *Star life cycles*

the Moon and providing a variety of activity stations to eliminate long lines at the telescope.

Star maps or charts represent stars as circles of varying sizes. The biggest circles represent the brightest stars, i.e., the ones you are most likely to see even from an urban site. For example, the seven stars of the Big Dipper are only the most prominent of the many stars which make up the constellation Ursa Major (the Great Bear). The Big Dipper is an asterism—an easily recognizable pattern of stars, but not one of the official 88 constellations.

Use simple, but accurate, representations of constellations for young observers. Trying to incorporate every faint star in a constellation in order to simulate some of the elaborate artistic representations found in books, can be confusing. Also, most students will be observing the sky from urban locations, where only the brightest stars (such as Orion's belt or the Big Dipper portion of Ursa Major) will be visible.

Constellation Viewers

Making constellation viewers reinforces the star patterns which students can observe in the night sky. After they have created several punched disks, students can trade disks to test their recognition of the common constellations. Two construction options are described below. See Figure 8.3 for sample constellation patterns.

Lesson Plan

OBJECTIVE:	To become familiar with the patterns of constellations and asterisms.
MATERIALS:	Cylindrical containers, e.g., Pringles chips cans; constellation pattern sheets; hammer(s) and nail(s); black butcher or construction paper circles the size of the can lid; black butcher paper for wrapping the can; gummed stars, crayons or markers; push pins; scraps of styrofoam or plywood; tape or glue; scissors. Optional: white pencils, crayons or chalk; patterned or clear contact paper. Alternative: toilet paper tube version (see last step in procedure)

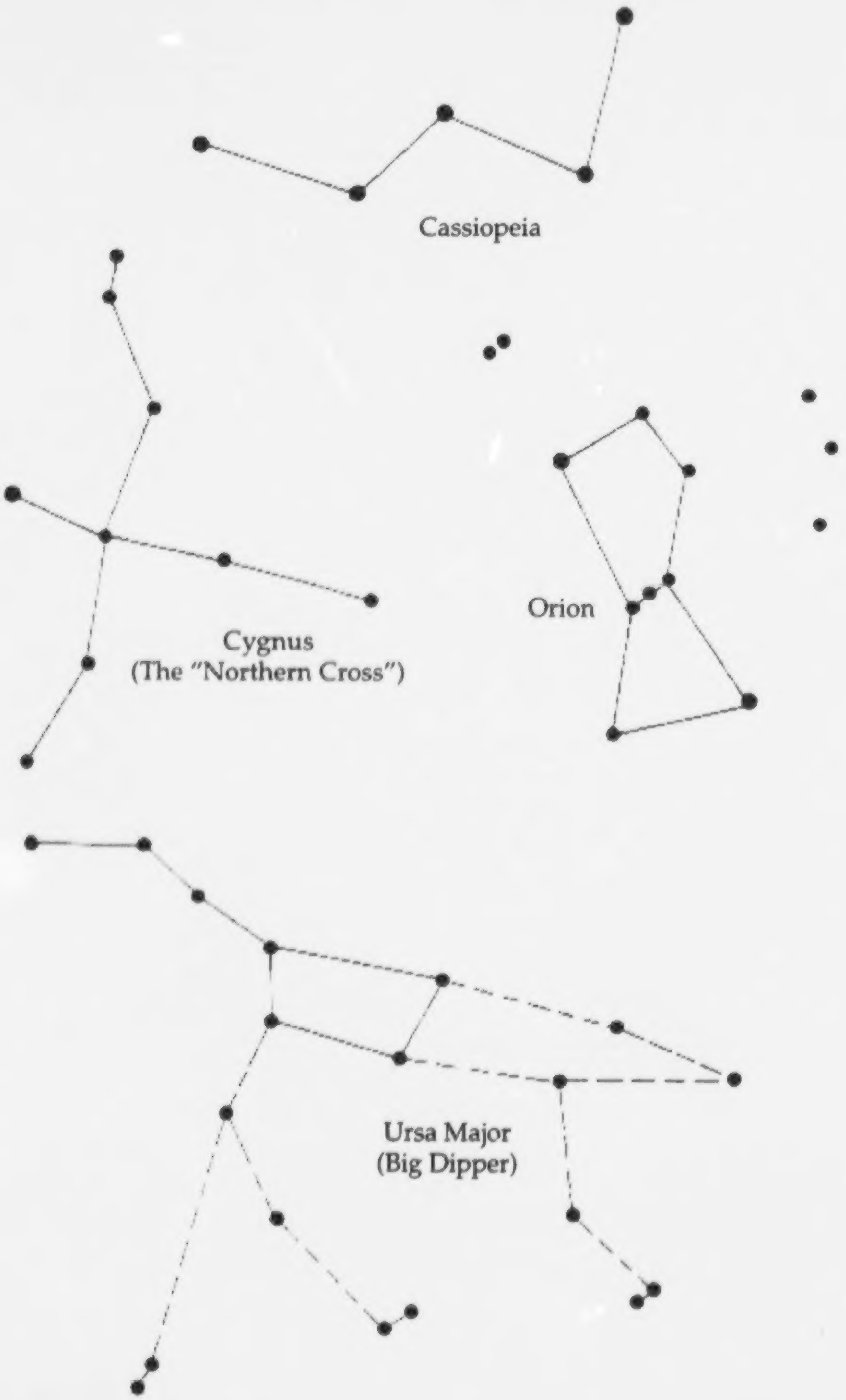
Cassiopeia
Cygnus
(The "Northern Cross")
Orion
Ursa Major
(Big Dipper)

Figure 8.3 *Star Constellation Patterns*

PROCEDURE

- Using the hammer and nail, punch a hole in the metal end of the Pringles can. This is the end through which you will view the constellations.
- Trace circles the size of the inside of the can lid onto black butcher or construction paper (or use previously-prepared circles, approx. 7.5 cm diameter).
- Choose a constellation pattern. Lay it on a black paper circle on the styrofoam or plywood. Use a push pin to transfer the star pattern onto the black paper circle.
- Optional: Use a white pencil, crayon or chalk to connect the stars into the constellation "picture" illustrated on the pattern sheet. The name of the constellation can be written on the front or back of the circle.
- Cut a piece of black butcher paper to fit around the Pringles can (about 23.3 cm tall by 23.7 cm around, or 9-3/8 x 9-5/8 inches). Tape or glue the black paper to the can.
- Use gummed stars, drawings, or patterned contact paper to decorate the can.
- Optional: If using gummed stars or drawings, cover the decorated can with a piece of clear contact paper to protect the artwork.
- Place one of the constellation circles into the plastic can lid, wrong side against the lid. Put the lid on the can. Hold the can up to the light and view the constellation through the nail hole in the metal end.
- Store the constellation circles inside the can lid.
- Optional: Students can trade viewers and try to identify each other's constellations.
- Optional: Use the smaller patterns with the cardboard tubes from toilet paper or paper towels. Punch out the patterns onto 4-5 inch (10-13 cm) squares of black paper. Fold the paper over the tube, right side of the constellation to the inside. Rubber band the paper around the tube.

Constellation Transformation Books

Constellations transformations were suggested to us by several primary grade bilingual teachers who had used a similar vocabulary building activity with their students. The simple, repetitive sentences (see patterns) work well with beginning readers. However, more proficient readers/writers can expand the activity to create their own short stories describing the new constellations they create. Working with the actual constellation patterns, rather than dropping paper stars randomly on a page or using a random pattern of dots, reinforces the actual patterns they can observe in the sky. See Figure 8.4 for a sample pattern and sentence.

Lesson Plan

OBJECTIVE:	Students will identify common constellation patterns. They will then create their own constellations using the same star patterns.
MATERIALS:	Xerox paper; construction paper; crayons or markers; staples; pencils; constellation patterns; text.

PROCEDURE:

- Introduce the students to some common constellations such as Orion, Ursa Major, or Cygnus (see Figure 8.3 for examples). Show examples of just the star patterns and the star patterns with the hunter, bear, swan, etc. drawn around the stars. Brainstorm ways that students can create their own constellations from these star patterns.
- Distribute constellation pattern (see Figure 8.3 for an example). It is important to use

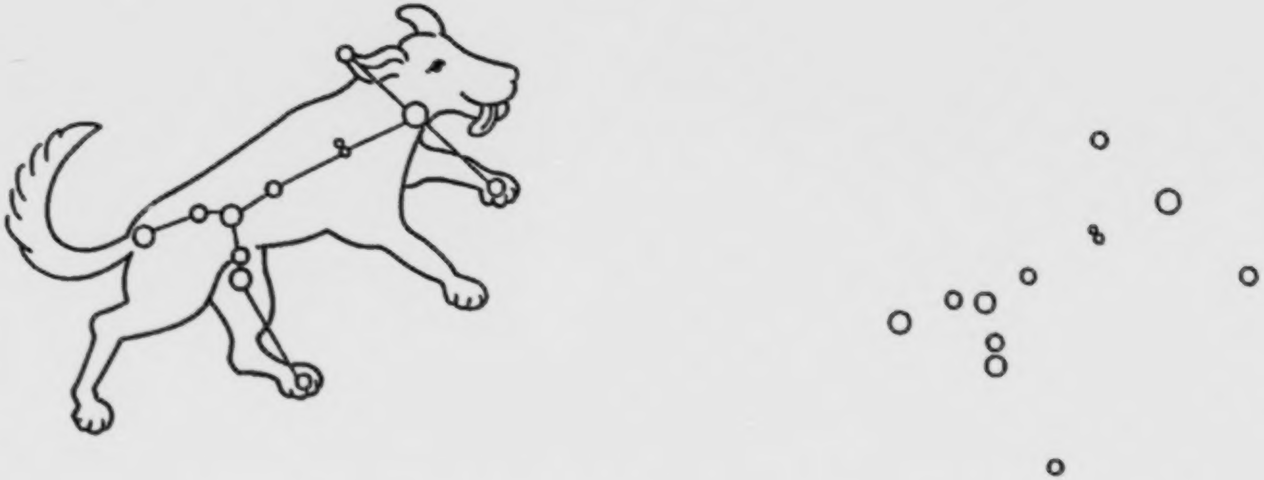

Figure 8.4 *Creating and describing new constellation patterns*

I used to be a dog, now I am ___ ____________ .

Antes era un perro, ahora soy ___ ____________ .

accurate star patterns so that the students will be able to recognize these constellations in the sky or planetarium.

- Ask the students to identify the pre-drawn constellations. Then ask the students to create their own "constellation" from the plain star pattern. Use crayons or markers to decorate the constellations.
- Have the students print the appropriate text (see Figure 4) under each constellation. For younger students, you may wish to print the text on your master copy, leaving only the blank spaces for the children to fill in.
- Have the students share their new star patterns with the class. Each student can make their own transformation book, or small groups can contribute to a collective book.

EXTENSIONS: Share myths and legends about the constellations with the students. Ask the students to write a legend about their created constellations.

Literature

The sky belongs to everyone—not just to astronomers, planetary scientists, and astrophysicists! For centuries people all over the globe observed the skies and created stories and sky pictures to describe what they saw. The official constellations, often bearing the names of characters from Greek and Roman mythology, were interpreted completely differently by observers in different times and places. Sharing a variety of stories with students can increase their awareness and appreciation of different cultures worldwide.

The following activities are meant to enhance and reinforce the science content, not to replace it. When used in conjunction with a lesson on constellations or better yet an evening observing session, these activities and stories extend the astronomy lesson into other areas of the curriculum and allow the students to respond creatively to the wonders of the night sky.

It is important when sharing myths and legends with the students to distinguish fanciful creativity from scientific fact. If our topic is the Moon, it is vital that the students understand the Moon as a place, much like the Earth—with solid rock underfoot, with mountains and valleys, and with soil on which men walked and left footprints over 25 years ago—so that they can enjoy fanciful stories without creating scientific misconceptions. It is fun for the students to realize that not everyone around the world would recognize the Man-in-the-Moon. Some children grow up seeing a fox, a rabbit, or an old woman and her pet wildcat on the face of the full moon. *Moontellers* (Moroney, 1995) is a good source of moon lore.

With stars and constellations, the students should understand that stars are balls of hot gases which come in different sizes and colors, that our Sun is a star, and that it provides the heat and light which allow life on Earth to flourish. Constellations are groups of stars with special names that people gave them long ago because they imagined "pictures" or shapes in the sky, just as we can imagine different shapes in clouds. With older children we develop the idea that the way we see the stars in a constellation is determined by our place in space (NSTW, 1995).

Some stories associated with the sky tried to explain how or why an object such as the Sun got into the sky; others sought to explain cycles such as day and night, seasons, or lunar phases; yet others provided a moral or lesson. Once students have some knowledge about the Sun, Moon, or stars, and after they have heard or read a variety of creative stories about these celestial objects, they can create their own short stories or descriptions about such phenomena as sun spots, why the Sun is hot and the Moon is cold, why the sun sets at the end of the day, etc. See Appendix A for more sources of literature.

Poetry can also be part of the astronomy lesson. In addition to published poetry, students can use their astronomy knowledge to compose cinquain, diamante, or name poems. One of our workshop participants composed a poem which not only reinforced the colors of stars, but which allowed her students to reinforce reading skills as they read the poem aloud singly or as a group.

Skylore Projects

While the projects described below have been classroom tested by teachers in grades K-8, primary grade teachers have expanded the given suggestions to include acting out stories, making simple costumes or headgear for the students, or having the storyteller wear a kimono (or other appropriate native costume). Songs and/or movement activities with a star theme can also be part of the astronomy unit. Primary grade teachers from both the ARTIST and ACCESS! programs have incorporated stars and constellations into their favorite art activities, such as creating a constellations quilt using batik, sponge painting on T-shirts, and folding origami stars.

Story Basket—Coyote and the Big Dipper

Lesson Plan

BACKGROUND:	This activity is based on a Native American interpretation of the Big Dipper. The patterns and story summary provided follow the version called "How Coyote Arranged the Night Sky" from *They Dance in the Sky* (Monroe & Williamson, 1987).
OBJECTIVE:	Students will explore the different artistic views of the Sun, Moon, and stars as expressed by ancient and contemporary cultures. They will re-tell a myth or legend for themselves or to peers, providing practice in storytelling, sequencing, listening, and comprehension.
MATERIALS:	story summary; box, basket, or other appropriate storage container; patterns (for tracing) or pictures of main characters; 1 large piece of fabric (about 1 sq. ft., 30 cm square); scraps of cloth, felt, oaktag; scissors; glue; plastic or wood figures, if appropriate.

PROCEDURE:

- Present grade-appropriate factual information on the Sun, Moon, or stars. Share an astronomical myth, legend, or folktale such as "How Coyote Arranged the Night Sky." A summary of the coyote story is at the end of this lesson plan.
- Assemble a story box, as described below.
- Discuss the origin of the story (historic time, location) and the differences between scientific information and legends.
- Allow the children (singly or in small groups) access to the story box so that they can use the manipulatives to re-tell the story.
- Stress that the stories were important to their originators and the story boxes should be treated gently. All small pieces must be wrapped in the background cloth and stored carefully in the box or basket.
- Allow other options for responding to the story, e.g., drawing, painting, using clay, or writing their own legend. Lay out the Big Dipper pattern on the classroom floor or playground and allow the students to assume the parts of the characters.

ASSEMBLY:

Choose a sturdy shoe box, basket, or other container for storing the background cloth and small pieces. Represent key figures and objects in the story with felt cut-outs, pictures glued to tagboard, or small figurines or recycled items. "Antique" items from yard sales often lend authenticity to the storytelling. (Patterns for the coyote story characters follow the lesson plan.)

Choose a piece of fabric to serve as a surface for the manipulatives during the storytelling. Wrap small pieces in this background cloth. Try to choose a color and type of fabric appropriate to the story. A piece of fabric about 1 foot (30 cm) square works well; however, the size really depends on the sizes and numbers of manipulatives included.

Assemble the manipulatives, wrap them in the background cloth, and place them in a sturdy box. Label the box with the name of the story (or with representative pictures, if students are not yet reading). Store the box where the students can access it.

STORY SUMMARY:

Once there was a curious coyote who lived with his friends, the five wolf brothers. Every day the wolf brothers and their dog would go hunting. When they came home, they shared their meat with coyote. They also talked around the campfire about something strange and frightening they had seen in the sky. But they would never tell coyote what it was.

Every night coyote would ask the wolf brothers what they had seen in the sky. His curiosity grew and grew. Finally one of the wolf brothers said, "Let's tell coyote what we have seen." They agreed to tell him that very night. The wolf brothers told coyote about two strange animals they had seen high in the sky. They were very brave hunters, but there was no way they could get near the creatures. Soon coyote had a plan!

Coyote gathered many arrows together and began shooting the arrows into the sky. The first arrow stuck. The second arrow stuck to the first, and the third arrow stuck to the second. After a while, there was a trail of arrows leading up into the sky.

The next morning coyote, the five wolf brothers, and their dog climbed the arrow trail. They climbed for many days and nights, and finally reached the sky. The two animals in the sky were fierce grizzly bears, and coyote was afraid. But the two youngest wolf brothers were not afraid. They approached the grizzly bears and nothing happened, so the next two wolf brothers followed. Finally, the oldest wolf brother and his dog joined the group.

Coyote admired the beautiful picture they made in the sky. He began to back down the trail of arrows, breaking off the arrows as he went. To this day, the wolf brothers and their dog face the two grizzly bears in the sky. We call this sky picture the Big Dipper. When Meadowlark sings at night, he is telling everyone to come and look at coyote's picture in the sky.

The grizzly bears are the stars in the Big Dipper's bowl that point to the North star. The youngest wolf brothers are the stars that face the bears across the bowl of the dipper. The middle wolf brothers are the first and last stars in the handle of the dipper. The oldest wolf brother and his dog are Mizar and Alcor, the two stars which appear as the middle star of the handle.

Origami—Magpies and the Milky Way

Lesson Plan

BACKGROUND: The story of the Weaving Princess and the Shepherd (or herdsman or farmer) can be found in both Chinese and Japanese traditions. Versions of this story are found in *A Song of Stars* (Birdseye, 1990) and *Legend of the Milky Way* (Lee, 1982). Other versions are found in *The Seventh Sister*

(Chang, 1994) and as "Magpies Across the Milky Way" (Baker, 1993) in Odyssey magazine.

Vega, the star represented by the Weaving Princess, is a prominent star in the constellation Lyra (the Harp). Altair, the star represented by the Herdsman, is a prominent star in the constellation Aquila (the Eagle). In the summer these two stars are separated by the Milky Way. Vega and Altair are part of an asterism—a prominent group of stars, but not one of the 88 designated constellations—called the Summer Triangle. The third star in the triangle is Deneb, located in the constellation Cygnus (the Swan), or the Northern Cross. Another common asterism is the Big Dipper, seven prominent stars within then constellation Ursa Major (the Great Bear).

OBJECTIVE: The students will learn about an Asian legend and festival, will practice an Asian art form, and will learn about three constellations, an asterism, and the Milky Way Galaxy.

MATERIALS: story summary; patterns for Altair, Vega; tape; scissors; crayons or markers (optional); origami paper or 6-8 in. (15-20 cm.) squares of bond paper.

PROCEDURE:

- Share one or more of the stories about the Milky Way and the magpies with the class. The *Odyssey* magazine article *Magpies Across the Milky Way* contains some information on the Japanese Tanabata festival, which is associated with the story of the Weaving Princess.
- Draw or find images to represent the Weaving Princess and Shepherd. Place them on oak tag or thin poster board. Cut them out, fold and affix to stands with tape. Option: Decorate the figures with crayons or markers.
- Show the students how to make origami birds. See figure 5 for a very simple pattern, or use any bird pattern of your choice. Make enough magpies to form a river between the figures of Tanabata and Hikoboshi.
- The science portion of the lesson can center on constellations and asterisms; unfortunately, the stars in the story are best visible in summer. Options: An observing night with an amateur astronomer or a trip to a planetarium.
- The science portion of the lesson can center on the Milky Way Galaxy and our own location in the universe. *My Place in Space* (Hirst & Hirst, 1988) details our universal "address" from street, city, country, etc. through Solar System, Galaxy, Supercluster, and beyond, giving the students an expanding sense of "neighborhood" from the familiar to the universal. The "Intergalactic Invitation" activity in the *Ranger Rick Nature Scope: Astronomy Adventures* (Braus, 1989) stresses the same theme.
- Option: Compare other cultures' views of the Milky Way. There are several Native American variations in *North American Indian Stories* (Mayo, 1990) and *They Dance in the Sky* (Monroe & Williamson, 1987).

STORY SUMMARY

Long ago there was a beautiful princess, the daughter of the Sky God. She was the most skillful weaver in the land, weaving beautiful cloth at her loom every day. One day she looked up from her loom and saw a herdsman at work. She fell in love with him at once. When the herdsman saw the princess at her window, he also fell in love.

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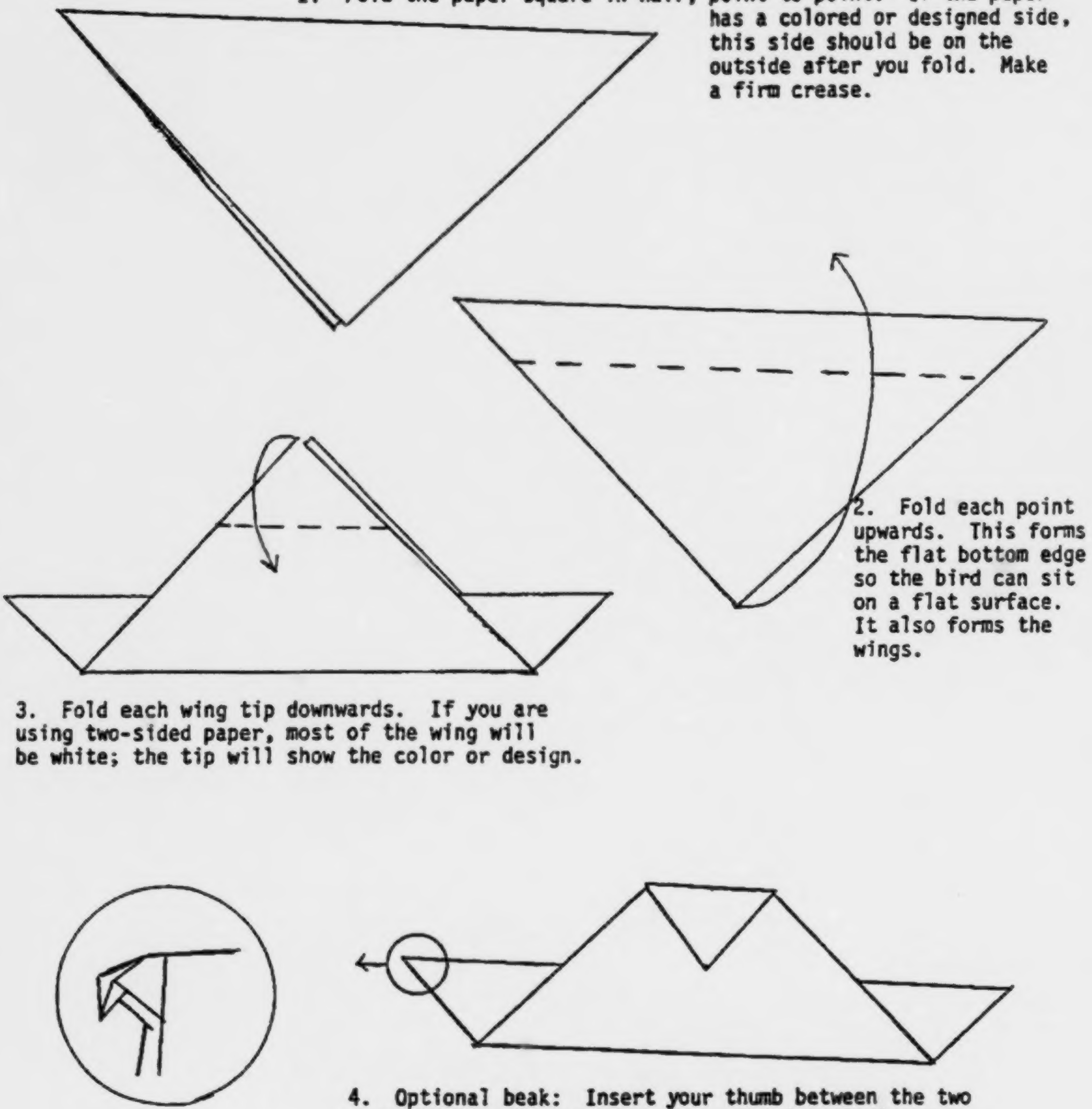
SUPER-SIMPLE ORIGAMI BIRD



1. Fold the paper square in half, point to point. If the paper has a colored or designed side, this side should be on the outside after you fold. Make a firm crease.

2. Fold each point upwards. This forms the flat bottom edge so the bird can sit on a flat surface. It also forms the wings.

3. Fold each wing tip downwards. If you are using two-sided paper, most of the wing will be white; the tip will show the color or design.

4. Optional beak: Insert your thumb between the two sides of the paper forming the point (circled). Press down on the fold with your forefinger. Pinch the sides of the head together to form a beak.

Figure 8.4 *Origami Bird*

The Weaving Princess begged her father to allow her to marry the poor herdsman. The Sky God agreed, and the two were very happy together. They were so happy that they each neglected their work. The princess forgot to weave her beautiful cloth, and the herdsman neglected his animals. The Sky God decided to punish them.

The Sky God placed the princess in the sky in one place, and the herdsman in the sky in another place. Between them he put a river of stars. They could see each other, but could not cross the river. The princess and herdsman returned to their work with great sadness.

The Sky God took pity on them and decided that if they worked hard at their tasks, he would allow the princess and the herdsman to meet one night each year. Toward the end of the summer, a great flock of magpies flew to the river of stars. They settled onto the water and formed a bridge for the princess and herdsman to cross. The next night the magpies were gone, and the princess and herdsman returned to their work for another year.

Conclusion

Children are exposed to the fiction of space almost every day of their lives on television and in the movies. They are also exposed to the realities of space in school and in the news. These children are the explorers of the future.

While many astronomers and science educators repeatedly say that astronomy is "developmentally inappropriate" for primary students, our results with second and third grade teachers present a different conclusion. Our site testing, teacher and student comments, and classroom visits have demonstrated the success of these activities with young students. The key to the success of these activities is their use of an integrated approach, integrating the science concepts into the existing classroom curriculum.

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Note

Full size copies of all patterns for the constellation viewers and constellation transformation books can be obtained from the authors.

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Chapter 9

The Mathematics and Science of Seeds

Gerald Wm. Foster

Thinking about the number and variety of seeds on this planet can boggle the human mind. They range in size from the large coconut to the tiny mustard seed. Their colors match the rainbow's spectrum while their textures and shapes are unparalleled in diversity. Seeds can spark a natural curiosity about living things and wonderment about their role in changing ancient civilizations.

This chapter presents seed activities to support the development of mental structures so essential for processing qualitative and quantitative information. "Mental structures are the processes we use to create relationships and to understand the data we take through our senses. In other words, they are the things we think with, whereas the content of our thought is what we think about"(Phillips & Phillips, 1994, p. 50-51).

Classifying and ordering are processes essential to creating and understanding sensory data. The diverse attributes of seeds challenge the imagination for grouping and regrouping them in a variety of ways. Classifying and ordering seeds provides opportunities for exploring the concept of number and mathematical operations such as adding, subtracting, multiplying, and dividing. The construction process of building spatial relations can be initiated by actively working with seeds. Arranging seeds in a variety of patterns can influence the understanding of volume, area, weight, measurement, and pictorial graphing.

The seed activities presented in this chapter are sequenced to reflect the developmental nature of understanding classification and ordering which is paralleled by development of spatial relations. The activities begin with an emphasis on classification and ordering, followed by activities that focus on spatial relations. Two appendices are included: one provides suggestions for using literature and the other provides extended activities for pursuing further inquiries about seeds and plants. Despite an attempt to present the following activities to parallel intellectual development of classification and seriation, there are no guarantees that children who progress through the activities will understand these concepts. Each child brings to the seed activities different backgrounds, interests, and understandings that affect what is learned. Children need a variety of hands-on experiences, over time, to internalize the concepts highlighted in this chapter. Using plant seeds is just one example of those experiences.

Materials for Activities

Use a variety of natural plant seeds. Seeds that are as small as, or smaller than, rice will be difficult for pre-school and primary grade children to handle. Seeds of this size or smaller can be examined in containers such as small plastic bags. Beans, peas, and corn are the most likely candidates for seed study, because they are the right size for handling and have diverse attributes. They are easily found at a variety of stores in every community. See figure 9.1 for a list of seeds and information on where they can be found.

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Type	Examples			
Beans	* pinto * black eye beans ** lupini beans	* lima * large lima ** koukiá beans	* red kidney ** fava beans	* navy beans ** Black turtle beans
Peas	* lentils	*green peas	* garbanzo (chick peas)	
Corn	*** sweet corn	*** field corn	* popcorn (yellow and white)	*** Indian corn
Other	*** pumpkin	*** watermelon	*** gourds	*** squash (acorn, butternut, and summer, etc.)

Asterisks denote where the listed seeds can be purchased: * grocery stores; ** ethnic food stores; *** garden centers/drugstores/hardware stores

Figure 9.1 *Types of seeds for investigations and where they can be purchased*

Other needed materials are:

Containers
- Plastic peanut butter jars of various sizes with labels removed, baby food jars, quart size resealable plastic bags.
- Trays: styrofoam meat trays, cafeteria trays, aluminum cookie trays.

Work stations
- Plastic table cloths.

Additional materials
- Pan balance or T-balance scales.
- Magnifying lenses.
- Fiction and nonfiction seed story books such as those listed in Appendix II.
- Potting soil.
- Styrofoam cups for planting seeds.

Managing Seed Activities

Each child should have his or her own set of equipment, because distractions are likely to occur if children are sharing the same materials. This is not to say that children can not interact with each other while investigating seeds. Materials should be easily accessible and visible to the teacher and children. Children can gather the necessary materials on their own, but they should be monitored and directed to take only the materials needed for a particular activity. The more extraneous materials they have in front of them, the less focused they become with the task at hand. For example, children need a bag of seeds for the classification activity to get an overall idea of all the attributes of different seeds. Magnifying lenses can be used later when children want to examine seeds in detail.

Since seeds can be easily spilled, spread a table cloth or something similar on the floor. The basic materials are the bag of seeds and a tray. Children can pour the seeds onto trays for examination. If seeds spill onto the table cloth, they can be picked up easily. The advantage of children working on the floor as compared to tables or desks is that the seeds or other materials are not going to fall off anything onto an unprotected floor.

Children will be pouring seeds from one container to another. Provide them with various sizes of clear plastic cups and glasses. In addition, they will need small plastic containers such as cough syrup measuring cups or party favor cups. Store the seeds in various sized plastic jars, such as peanut butter jars or in baby food jars. These containers of seeds will be used for counting and measuring volume. Classification bags (pint size and resealable) should contain a great variety of seeds. Put at least 20 seeds of each variety into each bag.

Teachers can create stations for each activity with the appropriate materials. For example, you might have bags of seed sets at a station called "Classification;" balances with plastic cups at a station called "Balancing and Weighing;" a variety of glasses and cups with jars of seeds at a station called "How many Seeds?" and glue, cardboard, markers, string, and a variety of seeds for a station called "Seed Art." By having stations, materials can be available at all times for children, and they can choose according to their interests and ability level.

Allow children to do different things. Even though the activities are listed as discrete activities, it is possible that a child who is classifying beans may begin counting them. Thus activities overlap each other, and one activity can lead to another. For organization of this chapter, the activities are described in detail as discrete activities rather than just general extensions of the first activity, classification.

Questioning and offering alternative suggestions are important strategies to use with children. They facilitate assessment and assist teachers in understanding what children are learning. Questions and suggestions also challenge children to probe deeper into the concept embedded within the activities. Each activity has a set of questions and suggestions. There are "why" questions to elicit relationship explanations, and "what," "where," "how," and "which" questions to elicit factual information. The questions are not listed in any particular order, nor are they required to be used. They are suggestions, and their use depends upon individual children and situations. As a teacher, you will develop your own questions and suggestions. The procedures for each activity are kept to a minimum and within each activity a section presents ideas to initiate the activity. These "beginnings" are kept simple so that children can work on their own without being dependent upon a teacher to lead them through the activity. However, keep in mind that some activities, such as balancing and counting seeds in jars, require more structure than classifying seeds. Observe how children begin the activities before deciding whether or not they need more direction to continue.

Activities

Classification and Ordering

Materials: plastic table cloth, trays, magnifying lenses, seed bags

Commentary: This activity allows free exploration of seed attributes leading to making groups according to the attributes.

Introduction: Here are many different seeds. See what you can find out about them.

Additional Questions And Suggestions:

How many different ways can you group your seeds? How many ways can you make groups? Can you make two piles with all of your seeds? Can you arrange your seeds from the smallest length to the longest? Hold up a seed and ask, "Where would this seed go in your arrangement?" Assign a label to each group and make combinations of 2-3 groups. Find the total number of seeds. For example, groups A, C, and F contain 47 seeds. Can you arrange your seeds from the lightest to the darkest color? How many seeds are in each group? How many seeds do you have if you combine two of the groups? How many seeds do you have if you take away ten (or some other number) of seeds from a particular group? How many seeds do you have when you make the biggest pile? What is the smallest seed in your bag? What is the largest seed in your bag? How many different seeds have the same shape, color, texture?

Concepts/Processes:

classification and ordering, counting, addition/subtraction, observing, questioning, predicting

Assessment:

Children who have had very little experience with grouping objects may begin by placing seeds haphazardly on the tray. Developmentally, children will exhibit different levels of pre-classification behaviors (Phillips, 1996). For example, they may begin by lining up the seeds in rows with no particular pattern or place seeds of the same kind together in rows. At the next level they will create pictures before making groups. However, you may also see combinations of these different levels as they progress from one to another. For example, children may make pictures with the beans and make groups as well. They may make rows and pictures. Classification is more than placing objects in groups. The act of classifying involves creating relationships between groups. This is necessary for understanding addition and subtraction. The classification relationships are between groups and an overall larger group. For example, a group of lima beans and a group of pinto beans belong to the larger group, beans. Moving beans back and forth between groups is addition and subtraction.

Children can place their groups on cards such as 5x7 index cards. Each card represents the boundaries for the group of seeds to distinguish one set from the other. By taking away or adding to the sets, children can explore addition and subtraction. When children are comfortable making groups, they can organize their groups according to the number of seeds in each one. Seeds can be added or taken away from the groups. Children can be given number symbols to represent the number of seeds in each group. Addition or subtraction signs can be provided with the number symbols for children to perform the mathematical operations.

Counting Seeds in Containers

Materials: jars filled with seeds; baby food jars, quart or pint plastic jars with lids, 3 oz. clear plastic cups, cough syrup measuring cups or party favor cups, and plastic vials.

Commentary: Children should work with one type of seed rather than mixing them together. Depending upon their age and experience, young children should work with large seeds such as lima beans if using pint or quart sized jars or with baby food jars if using small seeds.

Introduction: How many seeds are in the jar? Can you find a way to know exactly how many seeds are in the jar?

Additional Questions And Suggestions:

Can you find a way to know how many seeds are in the jars without counting every seed? How many seeds in this jar will go into the small vial? (Teacher selects the jars.) How many seeds will go in the 3 oz. cup? How many 3 oz. cups of seeds will it take to fill the pint sized jar? Count how many vials you have and the number of seeds you have in each vial to know how many seeds are in the quart sized jar. How high can you pile up a given number of seeds?

Concepts/Processes:

counting, addition/subtraction, multiplication/division, observing, predicting, estimating, using number, questioning.

Assessment:

This activity involves making predictions, estimating the number of seeds in containers, and learning to create multiple sets with the same number of seeds from the same container. Counting the number of seeds in each subset and the number of subsets required to figure the total number of seeds in a particular jar is the foundation for multiplication. Children who can do the reverse and determine the number of seeds in half (or some other portion) of the subsets are dividing.

Volume of Discontinuous Solid Objects

Materials: baby food jars and quart or pint plastic jars with lids filled with the same kind of seed, 3 oz. clear plastic cups, cough syrup measuring cups or party favor cups, and vials of varying sizes.

Commentary: This activity is an extension of the seed activity and learning that incorporated the concepts of multiplication and division. In this case the focus is on the volume of seeds within different containers.

Introduction: How many seeds in jar A will go into another jar? (Teacher selects a jar.)

Additional Questions And Suggestions:

How many of the seeds in jar A will it take to fill jar B? (Teacher selects jars for comparisons.) How many pinto beans will it take to fill jar A that contained 100 lima beans? If you pour out all of the pinto beans from jar A into these vials, how many vials will be filled by the pinto beans from jar A? Take a jar of seeds and see how many vials you can fill. How many seeds are in each vial? How many vials do you have? How many seeds do you have altogether? Take the next biggest sized cup. How many cups are needed to use all of your seeds? How many pea seeds are needed to fill the same number of cups? Fill a jar half full of bean seeds. Pour in enough water to cover them. Use a measuring cup, graduated cylinder or some other device so the amount of water added can be quantified. Measure the amount of water added to the jar. Look at the seeds the next day. Describe what you observed. How much bigger are the seeds? How much water is left in the jar? Where did the water go?

Concepts/Processes:

spatial relations, volume of solid, discontinuous objects, counting, addition/ subtracting, communicating, measuring, observing, predicting, using numbers, questioning.

Assessment:

Children are exploring the volume of containers by using solid, discrete objects. By pouring a given amount of seeds into different containers, they make comparisons of the volumes of a variety of containers. This can also be done by changing the type of seeds put into different sized containers. Asking children to predict and compare how many seeds will be needed to fill different containers will indicate what they understand.

Balancing and Weighing Seeds

Materials: Seed bags (see classification activity), equal arm balances or pan balances.

Commentary: Before children can understand standard units of weight, they must first explore the concept of weight by comparing the "heaviness" of objects. Balancing scales can be made by placing a ruler on a bundle of pencils bound together by a rubber band. Small plastic vials can be glued to each end of the ruler to hold beans. The pencils act as the fulcrum for balancing the ruler. The amount of material in an object (mass) determines how much that object weighs.

Introduction: See what you can find out about the weight of the seeds in your bag by balancing them on these scales.

Additional Questions And Suggestions:

How many of the smallest seeds does it take to equal the weight of the largest seed? Can you find two or more seeds that have the same weight but different shapes or sizes? How many lima beans equal the weight of ten pinto beans? Which seeds weigh the least? Which seeds weigh the same? Which seeds weigh the most? Place the seeds in order according to weight from the least to the greatest.

Concept/Processes:

balancing, weight, ratios/fractions, predictions, observing, measuring, questioning, communicating, using numbers

Assessment:

Can children make both ends of the balance parallel to the horizon? Children who can place seeds from the smallest to the greatest weight are experiencing another type of serial ordering. They are also learning about proportion and predictions if they can determine how many seeds of one kind balance a given number of seeds of another kind. Children are making comparisons of weights between bean seeds which is a nonstandard way to explore the idea of weight.

Seed Art and Geometry

Materials: A variety of seeds, glue, tag board, markers and pens. Surface areas to cover with seeds: plastic lids, desk or table tops, meat trays, cardboard or tag board cut into different shapes.

Commentary: The surface sizes children can cover and the patterns they make will depend upon the individual child. Some children may only be able to work with small areas or fill in patterns that already have boundaries such as outlined figures. Thick string, glued to cardboard, can form a physical boundary for figures. When children make patterns, shapes, or pictures, challenge them to either use the same kind of seeds or a variety of seeds. Patterns, shapes, and pictures can be made permanent by having children glue the seeds to cardboard or tag board.

Introduction: Using two different types of seeds, cover equal areas. What do you observe? Can you cover the entire surface of this object (e.g., meat tray) without any spaces between the seeds?

Additional Questions And Suggestions:

How many navy beans does it take to cover the same area as the largest seed? If you trace a large lima bean, how many seeds of other kinds will fit in your outline? Can you cover a surface using only one type of seed as opposed to using a variety of seeds? Can you make the same pattern of seeds that someone else (teacher or other children) has made just by looking at it? (Prepare some of your own seed art for children to try to duplicate.) Can you make the same picture, shape, or pattern using different kinds of seeds? Suggest patterns for children to try to make such as squares, circles, and triangles. Tell them to fill in the shape with seeds. Suggest making pictures of plants, animals, houses and other figures using seeds.

Concepts/Processes:

spatial relations, patterns, symmetry, area, predicting, communicating, questioning, measuring.

Assessment:

Children are learning about spatial relations when they make patterns, shapes, and pictures with seeds. By asking them to describe their patterns, they will reveal what they understand about surface area and the relationship of the seeds to each other. For example, a child might say, "The brown beans are next to the blue beans." The more precise they are in their description, the more they understand about spatial relations, such as location of objects on a given surface. You might ask, "In your picture, where are the beans that make up the eye of the dog?" A child, more than likely, will respond with, "On the dog's face!" However, probe further to determine if the child can give a more specific response than was given before. Agree with the child and say, "Yes, the eye is on the dog's face, but is there any other way to know exactly where the eye is?" The child might further explain, "They are at the top of the picture surrounded by brown beans." They may say, "They are five beans away from the upper corner," indicating specificity that is necessary to understanding measurement.

Nonstandard Linear Measurement

Materials: assorted seeds, small objects to measure.

Commentary: Before children learn to use standard linear measurement units, English or Metric, they need to compare lengths of objects to one another. Measuring length will also help in the understanding of perimeter.

Introduction: Compare the lengths of your seeds with each other.

Additional Questions And Suggestions:

How many navy beans equal the same length as a large lima bean? How many lima beans does it take to go around your desk? How many navy beans are equal to the length of your ruler? How many beans are equal to the length of one of your fingers, your arm, your foot? Which type of seed would take the most number to measure your finger? Why? Which bean would take the least number to measure your finger? Why? How can you determine which seed is the most appropriate to use to measure an object?

Concepts/Processes:

units of measurement, counting, ratios/fractions, observing, comparing, questioning, communicating, using numbers

Assessment:

Children can be assessed about the understanding of measurement by asking them to predict how many seeds it takes to equal the length of an object. The degree of accuracy can be used to determine the level of understanding. Also the process they use to make the prediction can indicate the level of understanding. Use the following question as an example: "How many lentils does it take to equal the length of a large paper clip?" The child may make the prediction based on what he or she knows about the number of lentils it takes to equal the length of a small paper clip or he or she may make a prediction based upon some other objects similar in length. This is a fairly accurate way of determining the length of the paper clip using lentils. The child may make a guess by picturing mentally the number of lentils lined up along side the paper clip. This is a less precise way of determining the length of the paper clip, but may prove to be fairly accurate for the child to make a prediction. Asking the child how he or she determined a number for his/her prediction will aid the teacher in understanding how the child thought about the task.

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Planting and Germinating Seeds

This activity is an extension because young children may not know where plants come from. Germinating seeds in soil gives children opportunities to examine the relationship between seeds and plants. It also provides an opportunity to chart plant growth by using objects. This is the beginning to understanding the purposes and functions of graphs.

Materials: Potting soil, styrofoam cups, seeds, trays, Ziploc bags, paper towels

Commentary: Here are three alternative ways to germinate seeds:

Alternative 1: Place soil in the cups, add seeds, and cover with soil. Add water to moisten the soil. Cups should have holes in the bottom to drain away excess water. Place cups on trays to catch the drainage water. Keep the soil moist to insure germination, but if the soil stays too wet the seeds will likely mold and die.

Alternative 2: Place two sheets of moist paper towel in a baggy so that they are flat and layered. Choose some bean seeds and place them between the two layers of moist paper towel. Position them around the edges of the Ziploc bag, so that when the seeds germinate, the growth of the roots and stems are clearly observable. To keep the seeds in place, use a stapler and place staples through the bag and paper towels near each seed. Hang the bags somewhere in the room. Rotate some of the bags on a daily basis.

Caution: Seeds may become moldy. To prevent mold growth, the teacher should rinse them in a very dilute solution of chlorine bleach before placing them in the bags.

Alternative 3: Germinate seeds in a sprouting jar. These jars are used to grow sprouts for fresh vegetable salads. Typically, these containers are quart-sized and made of amber colored glass. The lid consists of a hollow rim with window screening in the center. Depending upon the seed mixture, add approximately an eighth of a cup of seeds to the jar. Fill the jar with water, and shake and swirl the seeds in the water. Drain the water. Add water again, rinse the seeds, and drain the water. Store the container in a cool place such as a refrigerator. Rinse and drain the seeds on a daily basis to prevent the seeds from molding. A variety of seeds can be used but, again, bean seeds are a more appropriate size than most other kinds of seeds for observing the development of plant parts. Individual sprouted seeds can be removed from the jar for examination of their roots, stems, and leaves at various stages of development.

Additional Questions And Suggestions:

How many days will it take before the seeds begin to sprout into plants? How many of the seeds will grow? How many seeds actually grew from the ones planted? Do all seeds grow into the same plants? Do all seeds sprout in the same number of days? Compare the germination of the seeds in the bags that are rotated and those that are not rotated. What do you notice about the positions of the roots and stems? Using the seeds that are germinating in pots, measure the height of plant growth on a daily basis by using paper clips or some other nonstandard unit of measurement. Children can mark the calendar for each day that the seeds have not sprouted and make pictorial graphs to represent their data. For example, the number of beans planted could be glued to a sheet of paper with a row of beans next to them to represent how many actually germinated, or the paper clip lengths of the plants could be displayed by hanging them. Paper clips can be added to the chain as the plant grows.

Concepts/Processes:

measurement, graphing, predicting, communicating, using numbers, interpreting data, measuring, observing, questioning, using numbers.

Assessment:

Children can make predictions and comparisons of the pictographs that they make. They can compare plant growth of different kinds of seeds or changes within the same kind by referring to the pictographs.

Summary

Except for the final activity, *Planting and Germinating Seeds*, different objects could be substituted for seeds in the activities that have been presented. To be effective, the sets of objects used, such as buttons, must be plentiful and have diverse attributes. Seeds are plentiful with diverse attributes, readily available, inexpensive, and easy to store. Seeds are good objects to use because they are familiar to children as foods and as seeds for growing vegetables and flowering plants. The main purpose of the activities is to support the development of intelligence by presenting a variety of ways to manipulate seeds that involve inquiry and mathematical relationships. Working with seeds also provides in-depth exploration of seeds from many diverse spatial relations (i.e., counting, volume, and patterns). The shapes are ideal for filling containers and creating art.

> Intelligence cannot develop without matter to think about. Making new connections depends on knowing enough about something in the first place to provide a basis for thinking of other things to do —of other questions to ask— that demand more complex connections in order to make sense. The more ideas about something people already have at their disposal, the more ideas occur and the more they can coordinate to build up still more complicated schemes. (Duckworth, 1987, p. 14)

Intellectual development is stimulated through questioning, which encourages curiosity and the desire to know more than is already known. From the learner's viewpoint, questions provide the stimulus for in-depth learning. From the teacher's viewpoint, questions provide information about what has been learned. Because of the importance of questioning, additional questions about seeds are provided in Appendix A to promote inquiry beyond an exploration of the physical attributes of seeds. Working with seeds can also provide the stimulus and desire to read about seeds. Appendix B provides some suggestions for integrating literature and reading with the use of seeds in the classroom. This Appendix includes an annotated bibliography of fiction and nonfiction books about seeds.

About the Author

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Appendix A

Additional Activities and Questions

Generating additional activities from questions about seeds

The following are examples of questions that can lead to a variety of investigative activities: What seeds can be eaten? What animals eat seeds? What seeds are used to make cereals? What seeds can you find outdoors when you walk through the woods, fields, playgrounds, and yards? What time of the year do you find seeds outdoors?

Generating questions from additional seed activities

The following activities represent a few examples that illustrate how questions can be generated from an idea to help children continue to pursue investigating seeds:

Activity: ***Examine fruits and vegetables for seeds***

Commentary:

Fruits and vegetables may be green peppers, cucumbers, apples, pears, kiwi, oranges, and grapefruits. To examine them, slice them in different ways to expose the seeds.

Questions To Ask:

Which seeds will grow when planted? How many seeds are there in each type of fruit or vegetable? How do the different fruits and vegetables compare with the number of seeds they contain?

Activity: ***Making patterns from cross sections of fruits and vegetables***

Commentary:

Prints can be made by using tempera paints and cross sections of fruits and vegetables. Choose fruits and vegetables that have multiple seeds that are exposed when they are sliced. Before giving this activity to children, experiment with different fruits and vegetables to determine which ones will make clear prints. Also try cutting them in different ways before making prints. Green peppers, kiwi, and apples will produce clear prints. Try nuts like walnuts as well. Try to find exotic types of fruits. Many of these have unusual seed patterns in them.

Questions To Ask:

What shapes do the seeds create when you make prints on the paper? Can you get different shapes when the fruits are cut in different ways? Do you see different numbers of seeds when the fruit is cut in different ways?

Activity: ***Classify an array of nuts***

Commentary:

Collect nuts from trees and grocery stores. Tree nuts will be abundant in the fall, and nuts in grocery stores are available during the holidays.

Questions To Ask:

What shapes do nuts have? What are the colors of nuts? Are there certain shades of a particular color? How would you describe the texture of the nuts? How do their weights compare with each other? If you open them, what do they look like inside? What part of the nut will grow into a plant? How do nuts compare with other seeds you have been working with? How are nuts, seeds, and beans the same or different from each other?

Appendix B

Integration of Literature and Seeds

Children can make up stories that accompany seed art, weighing seeds, and counting seeds in jars or their imaginative fantasies. For example, children might make up a story about a grocery store that sells seeds in different containers. They may make up a story using seeds as money for buying and selling grocery store items or about a magical seed that produces popcorn that pops right on the plant. Have an abundance of pictures and minimal word books about seeds and plants available for children to look at and read.

The following are suggested books.

Bailey, P. (1975). *Duey's tale.* New York: Harcourt Brace, Janovich.

A maple seedling becomes separated from the mother tree.

Bates, J. (1991). *Seeds to plants.* New York: Gloucester Press.

Explores the biology of seeds and how they develop into plants.

Bunting, E. (1993). *Someday a tree.* New York: Clarion.

A young, girl, her parents and their neighbors try to save an old oak tree that has been poisoned by pollution.

Carle, E. (1987). *The tiny seed.* Natick, MA: Picture Book Studio.

A simple description of a flowering plant's life cycle through the seasons.

Cavagnaro, D. (1979). *The pumpkin people.* San Francisco: Sierra Club Books.

A young boy watches the seeds he plants in the garden.

Cutting, B. (1992). *Seeds, seeds, seeds.* Bothell, WA: The Wright Group.

Presents simple photographs of different types of seeds and what they produce.

Demi. (1990). *The empty pot.* New York: Holt.

When Ping admits that he is the only child in China unable to grow a flower from the seeds distributed by the emperor, he is rewarded for his honesty.

Dietl, V, (1993). *The plant-and-grow project book.* New York: Sterling Publishing Co.

Simple projects for growing plants from seeds and sprouts.

Henry, P. (1993). *Great seed mystery for kids.* New York: Aron Books.

Projects and experiments demonstrate the significance of seeds, how they grow, and how to plant and care for gardens.

Jennings, T. (1988). *Seeds and seedlings.* Chicago: Children's Press.

Describes the seeds produced by different kinds of plants, how they spread, germinate, and grow into a new plant. Includes study questions, activities, and experiments.

Kanno, W. (1984). *Bags the lamb.* Provo, UT: Aro Publishing Co.

A lamb eats magic seeds.

Lauber, P. (1981). *Seeds pop, stick, and slide.* New York: Crown Publishers.

Text and photographs describe the many different ways that seeds travel and disperse.

Mitsumasa, A. (1995). *Anno's magic seeds.* New York: Philomel Books.

The reader is asked to perform a series of mathematical operations integrated into the story of a lazy man who plants magic seeds and reaps an increasingly abundant harvest.

Moncure, J. (1990). *How seeds travel: Popguns and parachutes.* Elgin, IL: Child's World.

Describes how animals, wind, water, and other methods of dispersal help to spread seeds to new places.

Moncure, J. (1978). *Tick tock, the popcorn clock.* Elgin, IL: Child's World , Chicago.

Children enact the cycle of popcorn growing from seeds into tall stalks, under the care of the farmer.

Overbeck, C. (1982). *How seeds travel.* Minneapolis, MN: Lerner Publications Co.
Describes how seeds are moved from place to place by wind, water, and animals and how they function in plant reproduction.

Savatas, L. (1976). *Dandelion.* New York: Doubleday.
Describes the life of a dandelion from the time it is an airborne seed until the flower is able to provide new seeds.

Selsam, M., & Wexler, J. (1980). *Eat the fruit, plant the seed.* New York: Morrow.
Gives direction for growing plants from the seeds found inside avocados, papayas, citrus fruit, mangos, pomegranates, and kiwis.

Tant, C. (1992). *Seeds, etc.: A guide for parents and teachers, and students.* Angleton, TX: Biotech Publications.
Provides information on the structure, function, and development of seeds, and suggestions for experiments and science fair projects to explore these topics.

Titherington, J. (1986). *Pumpkin, pumpkin.* New York: Greenwillow Books.
Jamie plants a pumpkin seed and after watching it grow, carves it , and saves some seeds to plant in the spring.

Webster, V. (1977). *From one seed.* New York: D. Mckay Co.
Introduces the seed, that part of a plant which contains the beginning of a seedling and enough food to start its growth.

Williams, V. (1986). *Cherries and cherry pits.* New York: Greenwillow Books.
Bidemmi draws pictures and tells stories about cherries.

Wyler, R. (1986). *Science fun with peanuts and popcorn.* New York: J. Messier.
Experiments for home or the classroom with seeds and plants, showing what is inside seeds, how roots form, and how plants grow.

Chapter 10

Optimizing Activities to Meet the Needs of Young Children Gifted in Mathematics and Science

James J. Watters & Carmel M. Diezmann

Every person living in society needs to understand his or her social environment. Through civics we learn about politics; through economics we learn about commerce and international relationships; and through science we learn about the natural and technological world. Identifying the patterns and relationships in these domains requires mathematics. Thus, a goal of education is to develop scientifically and mathematically literate people. Enlightenment is the first step in empowerment for the citizen. The early stages of schooling should provide opportunities for children to develop the learning strategies that are necessary for exploration and investigation in order to make sense of their natural and social world. While schools provide opportunities for all children to become literate, there will be some children who exhibit a strong interest and possess exceptional gifts in mathematics or science.

Gifted children exhibit learning characteristics that are substantially different from their age peers. If teachers are to cater to students with a variety of social and cultural backgrounds, educational experiences, and physical and intellectual capacities, they must recognize individual differences and specific needs. The implication is that curricula have to be differentiated to cope with the heterogeneity of each classroom. Classroom teachers assume an extremely important role in establishing the learning environment that will enable all children to achieve. Gifted children, like all special learners, need different support to that required by their age peers if they are to fully realize their potential.

This chapter is about the characteristics and needs of young gifted children and an approach to teaching which caters to gifted children within the regular classroom. The approach is illustrated by the implementation of a set of activities for teaching science and mathematics. We draw on our experiences in catering to gifted young children through extension programs for which the strategies and activities were developed. Most of the activities can be implemented with all children, however the gifted perform and benefit especially from these activities if we capitalize on the full opportunities inherent in the tasks. The activities have also been taken up by many pre-service and practicing teachers. We are encouraged that our experiences have value for the teaching of science and mathematics in classrooms with heterogeneous groups of children. Indeed the challenge of catering to the gifted makes us examine our own practices to ensure that the needs of all individuals, including the gifted, are met within the classroom. Our response, therefore, is to share our ideas with readers seeking to improve the teaching of science and mathematics. The chapter is organized in four parts: Part 1, *Young gifted children*, discusses the diversity of giftedness; Part 2, *Integration of mathematics and science*, explores the relationship of mathematics and science; Part 3, *Meeting the diverse needs of the young gifted child*, describes the needs of gifted children and strategies for meeting these needs; and Part 4, *Sample program of activities*, presents a synopsis of a series of activities that the authors have implemented.

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Part 1. Young Gifted Children

The exceptionally bright and enthusiastic child who arrives at school on his or her first day with a thirst for knowledge, a curiosity about the world, and the confidence and facility to explore the unknown can be a challenge for the most dedicated early childhood teacher. The types of children we describe may be represented in every new class starting each year. These children signal their intellectual giftedness through their vast store of information, insightful ideas, and enthusiasm. As these children are comparatively advanced readers and are self-motivated, they actively seek new ideas and experiences. However, during the early years of their schooling they may be confronted with major dilemmas in fitting into an environment that is often unsuited to their level of learning. More often than not they are unchallenged by routine classroom tasks. In addition, a potential difficulty is their isolation from children with similar abilities with whom they can share interests. Although many gifted children do achieve at routine classroom activities, they often seek further challenge outside the classroom. For others, frustration sets in and they acquiesce to mediocrity thus failing to demonstrate their extraordinary gifts. Some gifted children may withdraw or develop behavioral problems in the classroom if their needs are not met. Thus, classrooms contain both achieving and underachieving gifted children who all need special support.

When teachers meet gifted children they are very quickly made aware of their precocity in mathematics, science and often computer technology. However, gifted children display a range of characteristics. To elaborate on the notion of giftedness we will examine the classroom behaviors of five young children identified as gifted: Gordon, Kathy, Martin, Sally, and Aaron. All these children were between five and eight years of age and attended an enrichment program run at the university. Gordon, Kathy, Martin, Sally, and Aaron represent a cross-section of children with diverse interests, abilities, and achievement levels but they were all capable of performance at levels far above their age peers given the appropriate opportunity.

Gordon and Kathy represent traditional high achievers in classroom activities and are easily recognized by teachers who described them as high achieving, cooperative, and insightful students who used advanced vocabulary, had a quick recall of factual information, and were consistent in completing tasks. Both were task oriented, motivated, confident, quiet, and socially well adapted. Gordon tended to work alone and was content to be involved in long term tasks which he fully committed himself to completing. Kathy was observed to work quickly. She was reflective, self assured, and quietly assertive, and had won a range of state awards for essays, science projects, and mathematics competitions at an exceptionally young age. Both Gordon and Kathy were noted for their reflective behavior in which they thought over, and could talk about, the strategies that they had used in problem solving.

Martin was also a high achiever, but he demonstrated lateral thinking approaches to problem solving, and was under pressure to conform to the teacher's perceived "right way of doing things." Martin was also a reflective but a more divergent thinker than Gordon or Kathy. For example, his teacher commented that he "thinks differently and his interests vary from those of his peers." Although he was an enthusiastic contributor to the class, he was described by his teacher as one who frequently "drifts off." Martin demonstrated creative intelligence. He was a self-motivated, independent learner who sought and integrated information, which he followed through by generating unusual solutions to problems. However, teachers saw his performance as being atypical and possibly of concern. Furthermore, his mother was concerned about his interests and described her dilemma as one of confusion: Was Martin brilliant or strange? Martin described how difficult it was for him to talk with other children and how their reactions to his interests were negative.

Others like Sally and Aaron were a concern to their teachers and parents because they appeared to be performing below their potential. Sally's classroom performance was erratic and ranged from complete mastery to failure. She was a lateral thinker whose task commitment depended on her interest in the task and she made little effort in tasks in which she was not interested. She was strong willed, assertive, and atypical in her behavior and interests as a girl. She tended to be a tinkerer, pulling things apart and was keen to understand how technology worked incorporating her understanding into technical models. Thus, she demonstrated practical intelligence in that she sought useful solutions to problems. This practice is not usually observed or encouraged in girls. Furthermore, Sally was notably eccentric and unconventional in her behavior and dress. Even her parents commented that they saw her as very much like a boy. Although she may be less inclined to conform at this stage of her life, negative feedback may generate intrapersonal conflicts with her perceptions of self and in the future she may decide to conform to social expectations. Acceptance of eccentric behavior is important to avoid the stereotyping of girls that can lead to underachievement.

Similarly, Aaron was seen to be an underachiever despite being able to read from an early age. In class he was often disruptive if activities were not challenging. His teacher noted that although he became absorbed in science activities, and exhibited competence at tasks well beyond his age, he frequently failed to produce a written product and often left normal classroom tasks unfinished. He frequently made factual errors because he skipped details and tended to jump to conclusions without reflection. Although Aaron could perform advanced mathematical procedures, he was unable to link his answer to what was required in the problem. Indeed his demonstrated expertise was procedural rather than conceptual because he had been taught many algorithms by his parents, which he could mechanically apply without understanding the problems. However, his particular strengths did not lie in analytical or sequential reasoning but rather in the spatial domain. He was a strong visual thinker communicating very effectively through detailed diagrams and drawings in which he employed a range of elements, such as perspective and proportion, at a level well beyond his peers. He displayed talent in chess, three-dimensional construction, and in solving board puzzles. His parents considered him to be gifted in a range of activities including mathematics and music. They also pressured him to achieve by tutoring, and supported him by providing extra-curricular activities such as advanced music courses. Nevertheless, his performance in class on regular work was poor and a major concern to both his teacher and parents.

These five children display a range of behaviors that can be interpreted by considering their cognitive, metacognitive, and affective characteristics. Most of these children had been identified because of their extensive knowledge of scientific facts. However, gifted children differ in the expression of intelligence, which is demonstrated through a range of information processing or thinking skills. For example, Kathy and Gordon possess high logico-mathematical and linguistic skills, whereas Aaron does not seem to possess high levels of logico-mathematical reasoning but rather has strengths in spatial reasoning. High achievement in science and mathematics is traditionally associated with logico-mathematical intelligence (Gardner, 1983, 1993). However, many studies have suggested a correlation between high spatial intelligence and achievement in mathematics (Clements, 1981, 1983; Fennema & Tartre, 1985; Guay & McDaniel, 1977, Krutetskii, 1976). Spatial ability is also beneficial in science activities (Ault, 1994; Lord, 1987), and students with high spatial intelligence have tended to perform better in science tasks requiring problem solving than students of low spatial intelligence (Carter, Larussa & Bodner, 1987; Gabel & Bunce, 1994; Pribyl & Bodner, 1987). Thus, exceptional analytical and spatial skills are important pointers to children gifted in mathematics and science.

Good problem solving abilities and the development of a rich conceptual understanding requires reflection or metacognition. Metacognition is an awareness and control over one's own thinking. It is a process of reflecting on and monitoring problem solving behavior. Self awareness of what strategies to use and how to use them is the essence of metacognition. Metacognition is an important characteristic displayed by the gifted and is also one of the distinguishing characteristics of giftedness (Borkowski & Kurtz, 1984). Failure to be aware of their own problem solving strategies, knowledge system, and the lack of an appropriate context in which to work effectively can inhibit otherwise gifted children from realizing their potential and becoming producers of knowledge. This was especially the case with Aaron. Consequently, developing metacognition is an important goal in teaching gifted children.

Motivation plays an important part in the expression of giftedness (Renzulli, 1977). Although motivation is seen as an indicator of giftedness, children bored by classroom practices may be unable to express their gifts in ways valued by teachers or may be unwilling to excel due to negative peer pressure. Thus, they may not appear to be highly motivated and therefore encouraging motivation becomes a goal of teaching these children. Intrinsically motivated children are disposed to using personal strategies that lead to perfectionist performance in contrast to extrinsically motivated children who employ a greater reliance on recall in problem solving (Carr, 1990).

An important component of motivation is one's feeling of being able to cope in a challenging situation. This belief is termed self-efficacy (Bandura, 1986). Children with a high sense of self-efficacy are more likely to attempt new problems, persist longer in attempting to cope with situations, and are more resilient in the face of failure. In essence they are confident in their abilities. High achieving gifted children have a high sense of self-efficacy (Schack, 1989). For example, Kathy and Gordon were both particularly confident of their ability to solve problems and hence exemplified the importance of a high sense of self-efficacy.

Summary

Giftedness is characterized by the capacity to perform tasks and generate new knowledge in domains important to humanity. Identification needs to be based on a comprehensive multifaceted strategy. Characteristics such as precocious development, behavioral maturity, and exceptional learning abilities in school or at home may give some insight to the child's giftedness. Traditional high achieving children in the classroom may represent one group of such children, but many others who show extreme interest and ability in science and mathematics may also be highly gifted but fail to exhibit performance in routine classroom activities; hence, the need to provide opportunities for *all* children to engage in challenging activities. The demonstration of giftedness is contingent on the possession of an innate profile of high intelligence, a willingness to employ that intelligence, and an awareness of how to employ that intelligence. However, it is necessary for the teacher to establish an environment that facilitates the demonstration of gifts.

Part 2. Integration of Mathematics and Science

The integration of science and mathematics has benefits for all children through improved understanding and performance, and the development of positive attitudes towards science and mathematics (Berlin & White, 1993). This section focuses on the value of an integrated program in science and mathematics. The activities that we describe later in Part 4 assume an understanding of the role of mathematics and science in real world experiences. Although there is no consensus on what it means to integrate science and mathematics (Underhill, 1994), we adopt a tripartite viewpoint in implementing the activities encapsulating difference, congruence and complementarity (Figure 10.1).

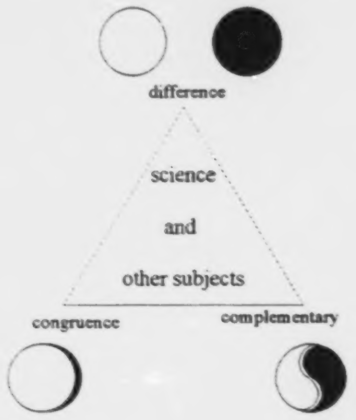


Figure 10.1 *Integration Model*

Difference

There are aspects of science and mathematics which are unrelated to the other because of the fundamental orientation of science toward patterns and relationships in nature (Steen, 1994), and mathematics towards the patterns and relationships themselves (Underhill, 1995). Science is about discovery of the world and seeking causal relationships about the behavior of natural systems. It is a way of thinking driven by a compulsion to explain nature. Science must be emphasized as not just a collection of facts about the world but as a way of explaining physical phenomena and establishing understanding of the relationships among phenomena. It is not about gathering information for information's sake but is about exploration, constructing personal understanding, making sense of the individual's own surroundings, and the organization and networking of knowledge. In contrast, the focus in mathematics is on identifying patterns and relationships within the data and the abstraction of inherent relationships. Thus science and mathematics are differentiated at the conceptual level, but they share processes and procedures.

Congruence

There is an overlap between science and mathematics in generic problem solving, reasoning, communication, and connections (Rutherford & Ahlgren, 1990; Underhill, 1995). Therefore, congruence of some aspects of science and mathematics is evident in how children learn about their world, that is, their inductive and deductive ways of knowing, and the process and thinking skills they employ in their quest for understanding. It follows that exploring the universe is a holistic experience in which science and mathematics are used to explore, analyze, and represent the natural world.

Complementarity

Science and mathematics are also complementary and interdependent: "Science provides mathematics with interesting problems to investigate, and mathematics provides science with powerful tools to use in analyzing data" (Rutherford & Ahlgren, 1990, p. 16-17). The understanding that develops from problem solving or scientific inquiry highlights the complementarity and interdependence of science and mathematics as the holistic way of learning through making connections. For example, the topic of weather can be explored through the measurement and graphing of temperature and rainfall, the drawing of daily weather charts, and a range of stories and songs about the weather. A spatially gifted child may be motivated to go beyond the simplistic drawings of daily weather charts to understand and use the traditional weather maps of meteorologists which integrate the science of weather and the mathematics of measurement.

Gifted children readily make connections; hence, an integrated approach mirrors their natural way of thinking about the world. Furthermore, integration is of particular benefit to gifted children because it leads to the development of perseverance in the face of challenging problems (House, 1990).

Part 3. Meeting the Diverse Needs of the Young Gifted Child in the Regular Classroom

Gifted children often come to school with an extremely positive attitude towards science and mathematics exemplified by interest, enthusiasm, curiosity, and a confidence in their ability to do science and mathematics, an attitude that may be in stark contrast to that of their peers or even some teachers. However, their achievement in these areas may not necessarily be indicative of, or commensurate with, their potential. To optimize the opportunities for achievement, the teacher needs to focus on establishing the appropriate environment and implementing strategies that attend to the special needs of gifted children whilst also providing opportunities for all children to be involved. It also needs to be recognized that gifted children are a heterogeneous cluster of individuals as we have already seen in the cases of Gordon, Kathy, Martin, Sally, and Aaron. Some of these children were not performing in the classroom because the tasks and the strategies used did not provide them with the opportunities to express their gifts. Therefore, teachers need to adapt activities and experiences specifically to meet the needs of these children and also to recognize that these needs vary according to the individual characteristics of gifted children. Our objective in teaching all children should be to support them to become autonomous learners. The potential for this to occur with gifted children in early childhood is real and needs to be a specific focus of teachers.

We will discuss an approach to addressing the needs of gifted children under six headings:

- *Expanding experiences.*
- *Cognitive apprenticeship.*
- *Cooperative groupwork.*
- *Social environment.*
- *Affect and attitudes.*
- *Opportunities for the creation of knowledge.*

These strategies are necessary to meet the needs of gifted children but they also enhance the learning environment of all children. This approach is adopted in implementing the set of activities described in the next section.

Expanding Experiences

The importance of expanding interests rests on the need to broaden children's conceptual knowledge. While a sound knowledge base in a particular area is important, the breadth is also significant in order to allow children to develop connected understandings. Some gifted children have special interests in narrow areas such as astronomy but have not had the incentive or opportunity to develop understandings in other areas. Similarly, in set curricula gifted children often master the particular level of work rapidly. These children should be encouraged to engage in work outside the standard curriculum to develop a breadth of knowledge. Experience in a range of conceptual areas allows children to think creatively and link ideas from one area to another. As autonomous learners, gifted children need to be able to develop and pursue areas of personal interest in depth from a range of choices. Betts (1985) contends that conceptual knowledge in areas of "passion," can provide opportunities for the development of higher order thinking skills. The development of cognitive skills that enable children to become autonomous is a primary need achievable through strategies adopted in an apprenticeship model.

Cognitive Apprenticeship

In an apprenticeship model of learning, a student works under the tutelage of a master craftsperson who by example, coaching, and encouragement introduces that person to the skills of the craft. Finally, the student is sufficiently skilled to become independent of the teacher. Thus, the teacher can employ with children a cognitive apprenticeship strategy that includes three components: demonstrating expert performance strategies, engaging in discourse in order to help students to internalize their own understandings, and finally allowing for autonomy (Collins, Brown & Newman, 1989; Jo, 1993; Roth, 1993). As students become more autonomous, teacher support should be withdrawn.

Demonstration of expert behavior by the teacher provides a model that gifted children can emulate. Modeling, coaching, and scaffolding, involving discourse and reflection equips students with critical and creative thinking skills. These skills are applied by exploring meaningful and open-ended tasks and activities. The strategies that teachers can adopt to implement cognitive apprenticeship and the related student behaviors are described in Figure 10.2. Cognitive apprenticeship implies responsibilities for both students and teachers. The teachers through modeling, coaching, and scaffolding provide the impetus for children to engage in articulation, reflection, and exploration.

Modeling	Teacher demonstrates the thought processes in expert performance.	Teacher: *I think that I would do it this way, lets try this, I know how to do it... I wonder why it is like that?*
Coaching	Teacher focuses on helping with problems while students are in the process of problem solving.	Teacher: *You are going well, Nearly there.*
Scaffolding	Teacher provides external problem solving support which is slowly withdrawn as students become more competent.	Teacher: *Well first, what do we know? The first step is to check...*
Articulation	Students verbalize or demonstrate their own knowledge and processes in a domain.	Teacher: *Tell me about what you have done? Why is it like that? How do you know that is right?*
Reflection	Students compare problem solving processes with peers or adult model.	Children: *How did you do it? I did it this way.*
Exploration	Students seek out independently new problems.	Opportunity and encouragement to explore.

Figure 10.2 *Elements of cognitive apprenticeship*
(adopted from Collins, Brown, & Newman, 1989)

Scaffolding is particularly important as it addresses both cognitive and metacognitive strategies (Vygotsky, 1978). The use of discourse involving questioning, debate, and argument is necessary so that children are encouraged to justify their knowledge. King (1991) describes one approach that involves students using planning, monitoring, and evaluative strategic questions: "What is the problem?" "Do we need a different strategy?" "What worked?" Differentiated questioning is a strategy whereby a teacher can cater to both gifted and mainstream children. In this strategy, the teacher directs higher order questions to the gifted child and demands higher order responses. While divergent thinking is advantageous to all children and can encourage higher level thinking, it is essential for gifted children to be challenged through questioning strategies that require them to draw upon diverse areas of knowledge, make logical connections, and justify their responses.

Cognitive apprenticeship can be very demanding as it requires extensive interaction with individual students. It can be facilitated through group work where students engage in a number of the processes with their peers.

Cooperative Grouping

Working together in small cooperative groups helps children to develop self-esteem, intragroup relationships, and to recognize and capitalize on each other's strengths and weaknesses. Ideally, membership is self-selected, but frequently groups can be deliberately constructed by the teacher to capitalize on or respond to individual differences in styles, interests, and capabilities. The research evidence supports the use of cooperative groups that are constructed with the goal of group achievement (Johnson & Johnson, 1995; Slavin, 1991). In our experience, group work facilitates the production of knowledge through sharing, brainstorming, and group synergism, and allows individuals to assume responsibilities and fulfill obligations to the group. In the classroom, clustering of children by ability groupings that reflect aptitude in particular areas is an effective strategy. Thus, gifted children should have an opportunity to apply previously learned basics to more advanced problems. This strategy alleviates boredom associated with repetitive learning and allows children to engage in learning more advanced skills.

Social Environment

Gifted children often express feelings of isolation in the classroom. Some have difficulty in communicating with classmates about their interests and passions. Being brought together with peers who listen and contribute ideas is a novel experience for many. They need opportunities to work together in situations where they are able to exchange ideas and information. Cooperative groupings based on ability is one strategy that can be adopted in the classroom but the general classroom environment that accepts and respects the contributions of gifted children is a priority. Social interactions are an important component of the learning environment, but the importance of the environment as a mediator of cognition, metacognition, and affect must be emphasized.

Many gifted children can contribute positively to classroom learning by presenting novel perspectives and demonstrations. Thus, in order to effectively teach science and mathematics to gifted children, a key initiative is for the teacher to provide an environment where the child engages in meaningful problem solving. This allows the child to elaborate, communicate, engage in argument, and debate with their peers or a teacher. Within this environment, tasks should be undertaken that are initiated by the child. For example, teachers can capitalize on experiences that children have out of class and permit them to explore these experiences individually. The gifted child is capable of extending such explorations into individual projects or reports.

An environment supportive of gifted children in a normal classroom can be established by the teacher who is sensitive to the characteristics of the gifted child. If, for a particular child, the environment at home or school lacks stimulation, challenge, or the appropriate modeling processes, the child may not develop his or her gifts into demonstrable talents. Lack of challenge however, is not the only difficulty that gifted children encounter. The experiences of young gifted children in school can be very negative. Feger and Prado (1986) suggest that the frequent passive or even active rejection by teachers of children's desire to learn more sometimes leads to lack of concentration, withdrawal, and even aggressiveness. They argue that such teacher behavior, in turn, inhibits the learning process so that the children enter a "spiral of disappointment." Further contributions to this state can be generated when a gifted child is supported by a sensitive and thoughtful teacher only to find that subsequent teachers ignore his or her talents. In some cases however, it only takes one key person to stimulate a child's interest in an area for that to become a critical event in that child's life leading to a successful career (Devlin & Williams, 1992). Frequently memories of specific events or episodes may impact significantly on learning, a so-called "critical incident" or "crystallizing memory" (Clements & Del Campo, 1989).

The ideal learning environment for young children is naturalistic and spontaneous, rather than formal and highly structured. The ideal environment allows children to engage in personally relevant learning in which they contribute a voice that is respected and also acknowledges the ways that children construct knowledge (Driver, Asoko, Leach, Mortimer, & Scott, 1994). Such an environment is represented by play, a topic to be addressed shortly.

Affect and Attitudes

Concomitant with cognitive development is the development of affect. The emotional status of gifted children is a prime concern. A focus on knowing and understanding self was an important objective of our intervention program (Sternberg 1994). By observing effective models and through vicarious experiences supported by realistic feedback, gifted children develop a sense of self-efficacy.

Thus, in the classroom realistic feedback is important and opportunities for this to happen depend on the types of tasks. All children should be challenged to the most appropriate level. Gifted children need help in setting goals that they can achieve but with effort. In classroom tasks we can expect different children to achieve at different standards. For example, in studying insects gifted children would be able and expected to explore issues such as taxonomy, or structure and function of various organs to a much greater depth than other children who may concentrate on more descriptive features. Success on these tasks would be different for individual children but acknowledgment of that success should be tailored to the teacher's expectations of each child.

Opportunities for the Creation of Knowledge

Children need opportunities to be producers of knowledge, especially the gifted who learn rapidly. Because of their holistic view of the world, curiosity, and often strong sense of social justice, they actively seek to understand and explore the world. Young children initially encounter and come to know the world through a range of everyday experiences that are personally relevant. The relevance should extend into the classroom. Thus, classroom activities should mimic these earlier experiences by contextualizing the topic and relating it to the children's life, thereby enabling the children to draw on multiple perspectives when solving related novel problems.

Real world problems are often ill-structured, have a minimum of clues, and may be solved through a variety of strategies that utilize mathematical and scientific knowledge. Science and mathematics are valued through "doing" rather than simply knowing (Brandwein, Morholt, & Abeles, 1988; National Council of Teachers of Mathematics, 1989). Many of these strategies draw upon intuition, holistic, and visual thinking rather than rule-based analytical procedures. In contrast, many classroom science and mathematics classes tend to be content oriented, unrelated to real world problems, and solutions are rote learned by many children. Thus, there is limited opportunity for the creation of knowledge. These conditions are inappropriate for gifted children because they fail to focus on the personal generation and application of knowledge.

Play as a Medium for Generating an Appropriate Environment

An environment based on structured play fulfills the requirements for effectively supporting gifted children and meeting the needs described. The engagement of children in constructive "play" can be a powerful opportunity for learning because it is conductive to intellectual and social growth (Berk, 1994). A curriculum grounded in play has a cycle of play-debrief-replay. The teacher organizes opportunities for play but must also facilitate classroom discussion in which students reflect on the object of their play and re-enact the experience through follow-up play. In this role the teacher provides the scaffolding through which the children become more responsible for the task being undertaken. Wasserman (1992) identifies five features of the play environment that promote cognitive and creative development; knowledge generation, promotion of risk-taking, no fear of failure, autonomous learning opportunities, and the encouragement of "what if" thinking through the use of manipulatives. The features of the play environment exemplify an ideal problem solving environment for young gifted children.

Summary

The types of problems investigated in the classroom are often controversial, as gifted children frequently have a strong sense of social justice and readily engage in an analysis of social issues, even at a young age. The development of enrichment activities in tandem with the regular classroom program can provide enrichment for gifted children in classes with their age peers through researching real world problems (National Council of Teachers of Mathematics, 1987). In a classroom enrichment model, the teacher adopts the role of planner and facilitator capitalizing on the children's curiosity and providing problems and discrepant experiences that challenge existing knowledge frameworks (Follis & Krockover, 1982).

Thus, gifted children's needs within the classroom can be accommodated initially using an essentially "ad hoc" individualized program. Alternatively, a formalized individual program can be planned by the teacher in consultation with the learning support teacher and a child's parents to meet that child's specific needs. Although formal individualized programs may be appropriate for the children's abilities, their development demands a degree of teacher expertise in understanding the needs of gifted children and presents the teacher with a substantial planning task. The following section discusses the types of activities that can be used with all children and have value for gifted children.

Part 4. Sample Program of Activities

Catering to gifted children can be done within the classroom, as a school-wide initiative or through external or pull-out programs. Enrichment programs have their own objectives, assumptions, and structures. However, in a number of aspects the models are similar and include raising awareness of science and mathematics, extending the interests of children, developing skills, and problem solving strategies and importantly, developing self-esteem and confidence in their abilities (Betts, 1985; DeBruin, Boellner, Flaskamp, & Sigler, 1993; Hoover, 1989; Renzulli & Reis, 1994). Since few enrichment programs specifically cater to young children with gifts in mathematics and science, we designed and implemented a set of activities for a program identified as the "Enrichment Network for the Very Young." These activities have been implemented in classrooms and external programs adopting the approach previously identified.

The approach we have adopted involves the components described previously: expanding experiences, cognitive apprenticeship, cooperative groups, establishing a social environment, development of affect, and knowledge creation. The approach is flexible, and hence components overlap and are integrated depending on reactions and feedback from children. The teacher's awareness of each child's developing interests and needs will influence the extent to which each component is implemented.

Overview of the Enrichment Network for the Very Young

The Enrichment Network caters to the needs of exceptionally gifted children in the five through eight years age range by providing enrichment opportunities for children with a strong interest in science and mathematics. The program grew out of a pragmatic need and demand identified by teachers and educational consultants who recognized that many young children were languishing in classrooms where their gifts were not being developed. In bringing together children of similar aptitude, we attempt to develop social skills, cooperative work and problem solving skills, and to broaden the experiences of children who may not have these opportunities in their normal classroom environment. An important aspect of the program is the challenge offered to young gifted children to work collaboratively with other children of similar aptitudes. The major ideas articulated previously that describe children's learning were piloted, evaluated, modified, and repiloted. Feedback from parents, teachers, children, staff and formal monitoring provided a wealth of insight into successful and not-so-successful strategies.

Identification of children is clearly an important aspect of the program as it is crucial that children are identified who will benefit intellectually, emotionally or socially from the program. Assessment is based on qualitative information and work samples. Anecdotal histories, counselor reports if available, and information from direct contact are also considered. Implementation of these strategies within a classroom or school-based program would be done with children who self-selected because of intrinsic interest. However, the approach implemented with individual children would depend on their individual characteristics and ability.

The program has three phases that have differing goals; a familiarization phase, a skill development phase, and an autonomous phase. The content within each phase is developed progressively in response to the interests and needs of individual children. The workshops emphasize challenging, open-ended, interactive problem solving tasks, and activities built around the integration of science and mathematics. Our experience has shown that it is possible to generate an effective learning environment built around the pursuit of knowledge. Implementing a program consistent with our philosophy requires us to react to individual children's interests. Therefore, each implementation of the Enrichment Network differs but a representative program is described below.

Activities from the Enrichment Program can be used independently within the regular classroom program and have been taught by us to young children in classrooms that comprised a range of children of different abilities.

A Sample Program of Activities

The initial phase is one of developing rapport and familiarization. The emphasis in the first few weeks is on establishing a warm, supportive and exciting environment in which children form social relationships with their peers and develop a rapport with the staff. Each session is of 90 minutes duration. The children are on a first name basis with the staff. Many of the children who attend the program are adult-oriented and engage in fluent conversation with staff. Gifted children's reluctance to discuss ideas with peers is understandable because they may have little in common intellectually with their chronological peers. Hence some of these children need to develop communication skills to interact appropriately with like-minded peers. Although many of these children have an amazing store of information, they may dominate discussions or not listen to or value the contributions of other children. Such behavior may mitigate against the development of links between ideas and reduce opportunities for the evaluation of alternate viewpoints (e.g. de Bono, 1992). Domination of the group may be seen as "showing off" and may also result in social isolation of the child. Other children may be reticent to proffer ideas in group discussions perhaps due to past experiences of isolation or indifference in their classroom environments, and need to be encouraged to participate. Communication skills are developed in the enrichment program by planning some activities which require team work, providing opportunities for all children to contribute to discussions, and by establishing an expectation that others listen to the speaker.

During this phase the activities used are proven activities which have been successfully used with gifted children of this age in previous programs. Through these activities the children are introduced to process skills which focus on cause and effect, and the influence of variables on the outcome of any problem. These activities also enabled the staff to become familiar with the children's interests, abilities, and needs. The floor is used as an activity area and cooperative play is encouraged. Whenever possible, outdoor activities are included and an area of lawn is frequently utilized for group activities. Program-home interaction is stimulated through personal contact with the parents, a newsletter, and by encouraging the children to do follow-up activities at home.

As the program progresses and more is known about the interests, abilities, and needs of each child the supportive environment provides the opportunity for enabling children to develop autonomy in learning. Hence, the activities serve a dual purpose; firstly, they encourage an interest in science and mathematics, and secondly, they address the needs of the gifted children.

Week 1: Space Travel

In the first session, the children were introduced to space travel through a video showing a clip of the first landing on the moon. The discussion that followed focused on team work among the astronauts and their ground crew, the construction of the rocket, and the path to the moon and back. The emphasis was on establishing conditions for reaching the moon and returning safely recognizing the constraints of gravity, atmosphere, time, and personal needs. The activity incorporated time-space relationships, distance, and direction. Hence, both mathematics and science were integrated.

As a follow-up to the discussion, the children made rockets from 2-dimensional and 3-dimensional construction materials and played a space board game that explored possible events in space, which helped to establish what knowledge children had about astronomical objects. The role of the atmosphere and gravity was explored in a series of activities that included making paper airplanes and parachutes. Shape, size, visualization (paper folding), and measurement were an integral part of these activities with an emphasis on structure and function relationships. For example, how does the behavior of the paper plane change if the design incorporates a wing of large surface area. Parachute making has been a particularly successful activity which all children enjoy. The activity is novel for most children, and a successful parachute can be quickly made from plastic, twine, and a bolt. The children were encouraged to help each other make their parachutes, and staff helped with tying knots.

Prior to the preparation of the parachutes, a discussion of the conditions necessary for flight was undertaken. Comparisons were drawn from the video of landing on the moon and landing of space vehicles on Earth where parachutes are frequently used to slow descent. Children gifted in science and mathematics, even at this young age, bring concepts such as air resistance and gravity into their explanations. After exploring the concept of air resistance, the children were encouraged to consider what variables might be important in the operation of their parachutes. In particular, ways of testing the effectiveness of their parachutes were discussed with an accompanying construction of the idea of a "fair test." Following the discussion in which the children developed ideas about how to release their parachutes, the parachutes were taken out of doors for testing (See Box 1).

The children dropped their parachutes from a height and, by watching others' parachutes, realized that the way they dropped the parachute affected its rate of descent and path. The children eagerly tried different ways of improving their parachute's descent. During the activity, the staff supported the children in developing problem solving skills through modeling and scaffolding. Additionally, encouragement and assistance in untangling parachutes was provided. A discussion of variables ensued and the children took their parachutes home in order to improve their design by changing variables e.g. the canopy material, the size of the bolt, the length of the string. This activity introduced the notion of variables, which was followed up in Week two. Some children returned the following week with "better" parachutes that were tested and the children justified the design.

Week 2: Travel

In the second week the concept of travel was explored. The mechanism of rocket propulsion was introduced by using a water rocket (Box 2). Observational skills were developed and used in order to analyze the important components of the process. The children were encouraged to design experiments which would test the importance of the relevant variables. They suggested variations such as the size of the bottle and the volume of water. Interestingly, the color of the water was thought by some children to be relevant to the height of the launch. Other children initially supported the idea of color as a critical variable, however color was rejected as an important variable by all children after several launches and subsequent discussion. The strategy employed in these types of activities was that of play-debrief-replay.

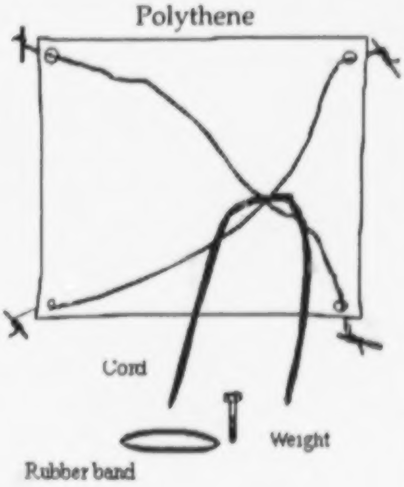
The children were also encouraged to work with their peers to construct either models of a lunar module or a moon buggy. The moon buggy, which they had learned about from the video, had to be functional in its design. The children also made a paper helicopter and explored the following variables and concepts (Box 3).

- *How can we get the helicopter to spin in the reverse direction?*
- *What happens if the weight is increased by adding paper clips?*
- *What happens if we try folding the blades to give them a curved profile?*
- *What variables could be used to define a good design?*
- *What effect does using papers of different masses have?*
- *Will the size of the helicopter be important?*
- *How do helicopters move forward?*
- *Why is there a small propeller on the tail of the helicopter?*
- *Trace the history of helicopters.*
- *Collect natural helicopters, for example, seeds from local trees.*

Making and Testing a Parachute

Background

The use of the parachute was first suggested by Leonardo da Vinci, but the first practical parachute was invented in the 1780s. The French aeronaut Jean Pierre Blanchard dropped a dog equipped with a parachute from a balloon in 1785, and in 1793 claimed to have made the first successful human parachute descent. Parachutes maximize the drag experienced by an object moving through air. Most parachutes are used to slow objects in free fall but are also used to slow aircraft landing in confined spaces and for high speed cars (e.g. dragsters).



Materials

Approximately 30 cm square piece of polyethylene (freezer separating film) serves as a canopy.
Two lengths of twine approximately 40-60 cm in length. These become the shroud lines.
A short (10 cm) length of twine.
A small vial or ballast weight.

Procedure

Demonstrate how to make the parachute step-by-step.
For young children it is best to prepare the strings beforehand and tie each end to a short (3 cm) piece of stick (skewer). The children can punch holes in each corner of the film.
The piece of stick with the string attached is threaded through one hole and pulled through. It is then threaded through the hole on the diagonally opposite corner.
The process is repeated for the other string so that the two strings cross in the middle.
The small piece of string is used to tie the stays together

(Outside) Have the children drop their parachutes from a height and observe the different ways that parachutes are dropped and their descent. Discuss "fair tests" *(All drop from the same height; release the parachute in the same way)*. Discuss when the parachute worked best and why (*An open canopy traps the most air underneath and slows the descent*).

- Have some children fill or half fill their vials with water to test whether adding some weight will improve the descent of the parachute. Compare the descent of the parachutes with empty, half full and full vials. A score chart could be kept.

Conclusion

Discuss with the children other variables that could be changed to improve the parachute (*size, shape and material of the canopy; length of the strings, the way the parachute is dropped*).

Box 1 *Making and Testing a Parachute*

The Water Rocket

The water rocket demonstrates Newton's Third Law, (For every action there is an equal and opposite reaction) and consists of a plastic drink bottle, and cork with a hole bored through the center snugly fitted with a football valve. The rocket is partially filled with water and air pumped into it with a bicycle pump. When the air pressure is sufficient the cork is ejected and the rocket is launched trailing a stream of water.

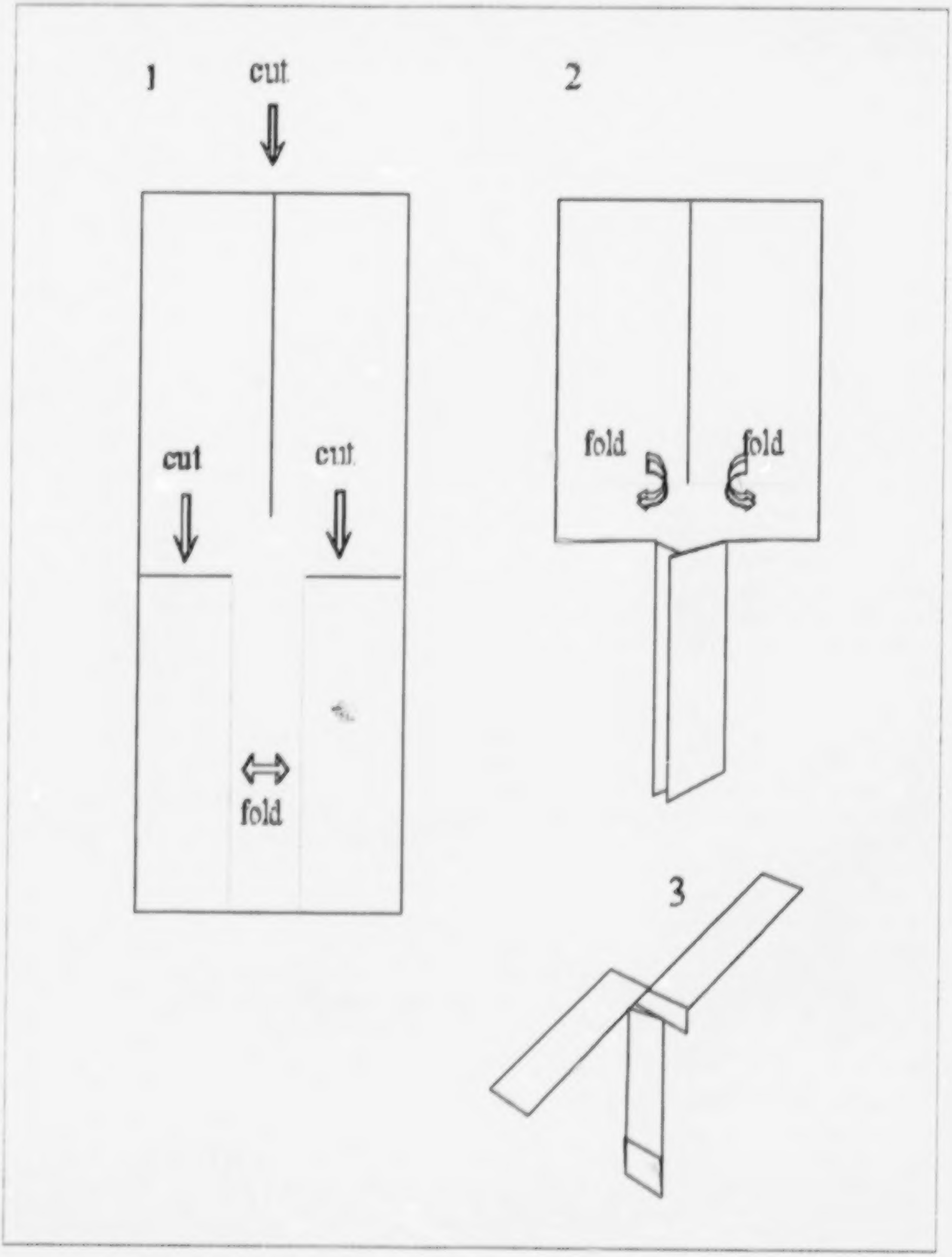
Variables that can be identified and manipulated include:

- Size of bottle
- Relative amounts of water (quarter, third, half, two thirds full or measured metrically in 100 ml increments)
- Number of compressions of the pump (with the stopper fully pushed in)
- Color of the water
- Brand of bottle
- Direction of launch

The children also are required to estimate the height that the rocket is launched by comparison with the adjacent building. They use clinometers to sight the highest point from a fixed observation area and use the angle as a relative measure of height.

The water rocket should be launched in an open space away from buildings. The rocket should be pointed vertically. The teacher should wear a pair of safety goggles and the children should stand several yards away. The rocket should *not* be launched if there is a strong wind.

Box 2 *Water Rocket Activity*


1
cut
cut
cut
fold
2
fold
fold
3

Box 3 *Helicopters*

Week 3: Sound

Rocketry from Week 2 was followed up with the launch of soda siphon rockets (Box 4). Links were made between the compressed air in the water rockets and the compressed carbon dioxide in the soda siphon capsules as propellants. The children's attention was directed to watching and listening carefully to the firing of the rocket. Connections between the various forms of rocket propulsion was made by a discussion of the sound of compressed gas being released. In addition, the concept of speed was developed by comparing the launch distance and the time taken. The importance of sound was a natural extension to this activity particularly as many of the children were very interested in music. Therefore, three sound activities were implemented.

The key objectives in these sound activities were to provide experiences that allowed the children to understand the causal relationship between sound, vibrating objects, and energy use. Attention to the characteristics of the sound was emphasized along with concepts such as pitch, loudness, and quality highlighted. Concepts of elasticity and energy were also introduced in the discussions. The activities involved the identification and manipulation of the variables which produce certain sounds. After listening to a variety of instruments (recorder, sonometer, or devices being played by the staff) the children made a simple drum with a cardboard cylinder, balloon, and rubber band.

The children explored a variety of sounds that could be made by hitting the drum in different ways. The children then made a second instrument of their own choice. Some children simply made a drum and added rice to make a shaker, while other children made more complex instruments such as a pan-pipe from straws. Children's manipulative skill levels varied greatly and the staff offered support where necessary. The variety of instruments enabled the children to associate pitch, loudness, and quality of sound with the physical attributes of the instruments (Box 5). The children enthusiastically used their instruments together to play and sing some songs.

Experience and Skill Development

The intent in the second three weeks was to continue to (a) broaden the children's experiences while encouraging the children to make choices, (b) develop manipulative skills in the use of scientific and other apparatus, and (c) continue to encourage peer and home interactions. The selection of activities in this phase of the program was monitored to ensure that all children covered a range of activities. The difficulty levels varied within some activities to cater for the abilities of the children.

Week 4: Animals

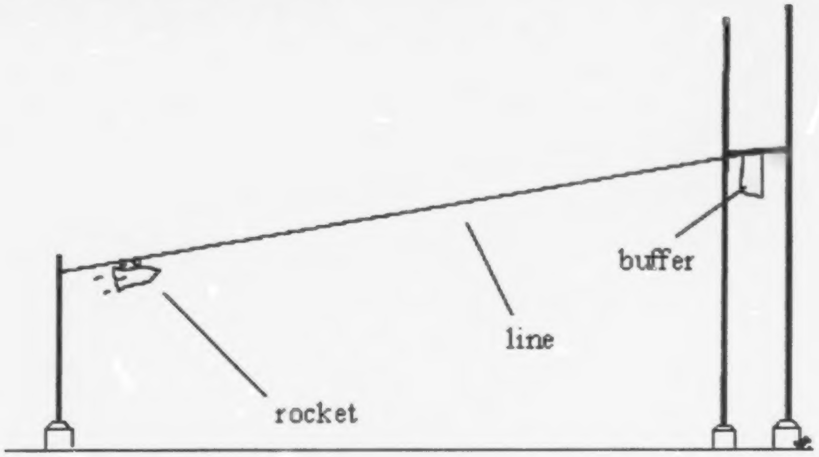
Animals was another topic which was of particular interest to the children. A range of activities were provided which involved observation of details, drawing, constructing models, and looking for similarities and differences between animals. Stuffed animals from a museum collection and microscopic animals were used in these activities. The latter provided an opportunity to use microscopes.

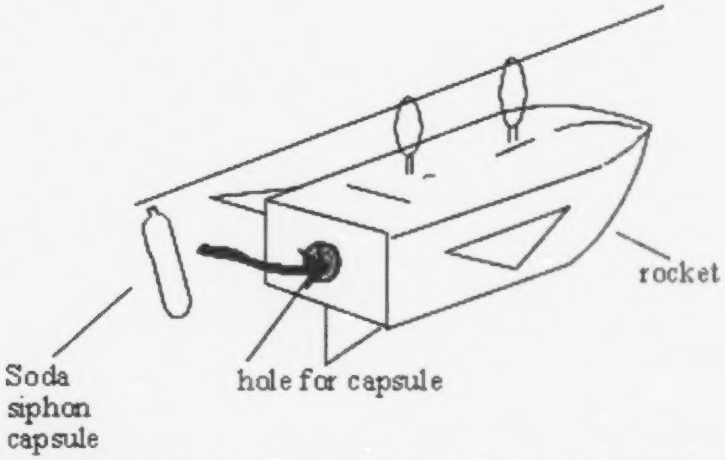
Drawings of animals were made in which accuracy rather than aesthetics was emphasized. The children's attention was focused on how two-dimensional and three-dimensional shapes were utilized in the drawing and modeling activities. In addition to drawing animals or microscope images of animals, children were shown how to do enlargements and reductions with grid paper (Box 6). Through this activity, the concepts of ratio and proportion were explored.

Soda Siphon Rocket

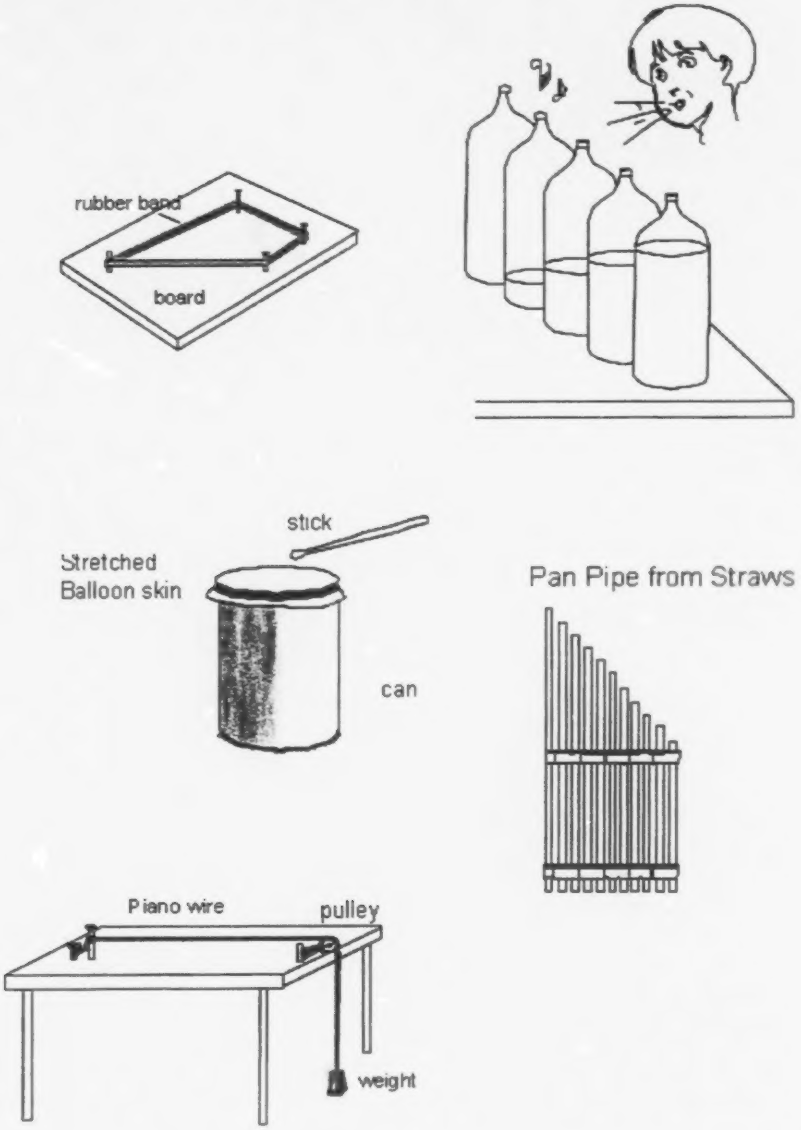
The rocket provides an extension to the previous activities on the water rocket. Links are made between the compressed air and compressed carbon dioxide in the soda bottles.

A high quality thick nylon cord should be securely fastened between two rigid vertical posts about 30 yards apart in an open space. The cord should be taut. The rocket is launched by piercing the CO_2 cartridges with a nail using a hammer. A small piece of wood can be cut out to hold the cartridge and nail in position. The rocket travels extremely fast and care *must* be taken to ensure that the rocket *cannot* come off the cord and that the cord is in good order and *will not* break. The teacher should practice launching the rocket prior to demonstrating it for children. The children should stand near the launch end of the cord but several yards away from the cord.





Box 4 *Soda Siphon Rocket*


rubber band
board
stick
Stretched
Balloon skin
can
Pan Pipe from Straws
Piano wire
pulley
weight

Box 5 *Selection of Sound Activities*

On another task, children made a three-dimensional animal from construction materials such as Legos, multi-link cubes, or clay. These constructions were built using a diagram consisting of the front, side and top perspectives of animals. The challenge in this task was for children to interpret two-dimensional drawings and construct accurate three-dimensional models without detailed instructions. The use of diagrams and models is important in science and mathematics as it is a valuable skill in problem solving.

Examination of animals such as insects and spiders with magnifying glasses and a dissection microscope proved to be a very successful activity. The examination of enlarged features of these animals was enthusiastically pursued by the children. Although they were generally reluctant to record observations in other contexts, several children made detailed drawings of what was seen under the microscope. The microscope also allowed for a discussion about structure function relationships in the anatomy of these animals, for example what purpose do hairs on the legs of bees have? (The collection of pollen from flowers). A sense of mathematical beauty in nature was made evident in the observation of shapes and patterns in the compound eyes of insects.

Week 5: The Forest

The children's interest in animals was further encouraged by visiting a nearby forest and trying to locate small animals. The purpose of this excursion was to explore natural interrelationships between organisms in the forest. Microenvironments in different parts of the forest were explored with data being collected on properties such as temperature, humidity, light intensity, and air movements. The location of various small animals was noted and potential food sources pointed out. The children were expected to be able to reconstruct the interrelationships back in the classroom.

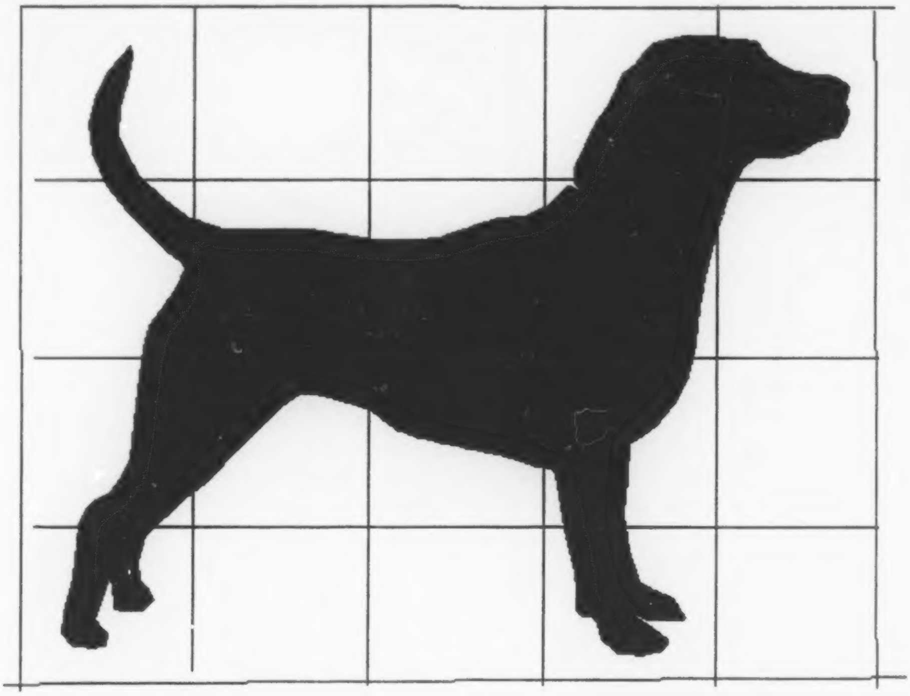
The reconstruction was undertaken through visual representation. The children collected discarded materials from the forest to reproduce a section of the forest in a collage with a partner. Music was used to recreate the mood of the forest while the children created their collages. All the sections of the collages were joined to provide a display of the total forest. Differing environments, food chains, food webs, and camouflage which had been discussed during the visit were included in several children's pictures. They delighted in watching other children and parents carefully peruse their pictures for hidden animals and animals that were food sources. Discussions included the effects of natural disasters or housing developments on food supply and animal populations. The light and temperature conditions in the forest environment also provided a contrast to conditions outside the forest. The following week during the astronomy evening, the night time environment of the forest was explored.

The forest excursion also proved to be an important stimulus to engage children in discussion of a controversial issue. Gifted children often have a strong passion and sense of social justice. Issues such as pollution and care for the environment are of concern to them. Their concerns are exceptionally strong and sincere for children so young. In one activity, the children were engaged in a reconstruction of an environmental impact study in which they were required to debate and report on issues concerning the hypothetical mining of gold in a national park in which lived an endangered species of animal. The children actively collaborated and presented thoughtful arguments in a variety of formats including posters and letters.

Week 6: The Night Sky

Many children expressed a strong interest in astronomy. Building on the activities engaged in Week 1 in which they examined some of the principles of space flight, an experience in observing the night sky was a logical extension. Furthermore, astronomy has always been a very popular session both with children and their parents and an evening workshop helps

Enlargements and Reductions



1. Choose an animal outline.
2. Place a plastic grid over the outline.
3. Draw the animal on a paper grid copying the animal square by square.
4. Draw the animal again and use a different sized grid paper. Were the squares larger or smaller than your first drawing? What happened to the size of the animal?
5. Can you think of how to make a very large or a very small drawing?

Box 6 *Enlargements and Reductions*

reinforce the social environment by drawing together parents, siblings, and children in cooperative exploration.

Given the subtropical geographical location of the program, astronomy is best done on a winter's night when there is an early sunset and the sky is clear. The activities included making a simple telescope; viewing the stars through a quality telescope; and making a planisphere and using it to locate constellations. The construction of a simple telescope was achieved easily with relatively inexpensive lenses (Box 7). One of these constellations was recreated on black cardboard with self-adhesive stars. A simple computer program provided different sky views for various locations throughout the world. The astronomy activities emphasized the relative position of the stars. Observation of the moons of Jupiter and the phase of Venus was exceptionally exciting not only for the children, but also for the parents who attended the session. Indeed, observation of parent-child interactions was illuminating as it informed us about the supportive family environment experienced by most of the participating children. Morse code with flashlights and lasers was also included as a means of communication which took advantage of the night darkness. In developing an understanding of astronomy and communication, codes, shapes, orientation, geographic location, time, and time zones were explored.

These activities drew heavily on spatial perception skills and a sense of time, distance and space. Being able to discern constellations of stars from a background, orienting oneself with respect to the stars and poles, comprehending the observed constant arrangement of stars in space, and interpreting skymaps are all practical applications involving spatial sense.

Autonomous Learner Phase

The last four weeks of the program were designed to allow the children to pursue topics in greater depth for extended periods of time using the staff as resource personnel. The children were encouraged to trial and justify their ideas and discuss them with peers and staff.

Weeks 7 and 8: Pet Paradise

The children's earlier interest in construction and animals was considered in developing an open-ended task that had children design and make a home, a means of transportation, or a form of entertainment for pets at a holiday village—Pet Paradise (Box 8). The fictional Pet Paradise was used to encourage divergent thinking and creativity. Construction was a popular activity in the early weeks of the program, and it was reintroduced after activities which helped to develop fine motor skills. Hence, the children were challenged to make something that fulfilled certain criteria, such as a vehicle suitable for pets. Because some children were novices with materials such as Capsela and Lego, a tutor worked with them in a small group, ready to lend a hand or make suggestions. At the conclusion of the session these children proudly showed their models to the whole group and explained the purpose of their model and how it worked. Experienced model builders also benefited as they could make more complex models because of the ready availability of materials. Fellow enthusiasts working cooperatively showed that they could overcome construction problems. The children used a variety of junk materials and commercial materials such as Lego, Capsela and Googleplex to produce a wonderful array of items in response to this task. Several children continued with their constructions in the following week; others produced alternate responses; and still others incorporated technology, for example, by adding lighting to their homes. At the conclusion of each week, there were discussions about the constructions. Electricity was of particular interest, and a small group of children worked with a mentor to produce a Christmas tree complete with flashing lights using a laboratory retort stand, batteries, bulbs, and wires.

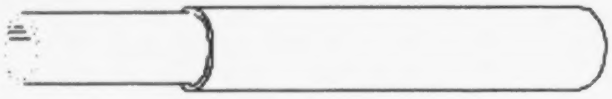
Construction of a Telescope

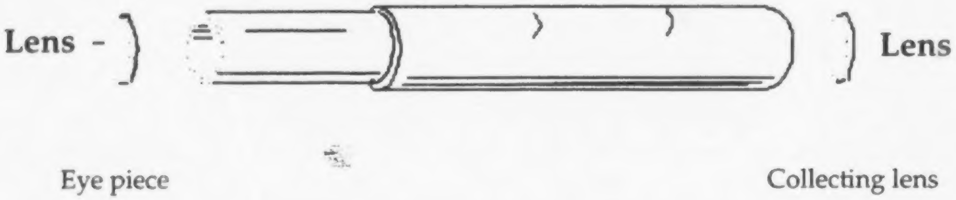
This telescope is easily made by children. However, it is advisable that the teacher practice and master the technique.

Requirements: Two simple biconvex lenses of diameter 50mm,(focal lengths 30 cm and 10 cm), two cardboard tubes approximately 25-30 cm long.

Firstly, the body of the telescope is made from two sheets of flexible cardboard. One sheet is rolled into a tube of diameter 50 mm and the other rolled to have a slightly larger diameter. It is simple to roll the smaller tube around the short focal length lens.

Secondly, fit the smaller tube snugly into the larger.





Finally the lenses are fitted into the tubes as shown and held in place with adhesive tape. The thicker, shorter focal length lens, if not already, is fitted into the 50 mm diameter tube and is held closest to the eye. The longer focal length lens is the collecting lens.

Sliding the tubes in and out helps to focus a distant object. The distant object will appear upside down.

Safety tip: Do not allow children to point the telescope at the sun.

Box 7 *Telescope making*

Weeks 9 and 10: Movement

During the previous two weeks, the children were very interested in models that moved. The final two weeks were planned to capitalize on this interest and link the ideas of movement to the other topics covered in the program. The children were presented with the challenge of exploring how a variety of things moved. Skeletons, magnets, boats, slime, Lego and Capsela were provided. Some children wanted to try all materials, while others spent the whole session

Pet Paradise

People go on holidays and have fun, but what about their pets? It's not much fun for a cat or a dog to spend a week in a kennel. Pet Paradise is a new holiday village which provides accommodation, transport and entertainment for pets.

Design and build accommodation, transport or a form of entertainment for pets.

1. Draw and write about your idea.
2. Build and label your product.
3. Draw a careful plan which shows the details of your product.
4. Explain your product to the rest of the builders and designers.

You must convince them why your product is a good idea!

Box 8 *Pet Paradise*

working on one task such as "skeletons." Two further activities were added in the last week, Lego Logo robotics and a range of games. Some children were proficient computer users and builders with Lego, so these children were shown how to control their models using Logo. This was of great interest to them and they quickly mastered simple programming. Programming in Logo requires an understanding of direction, angles, time, and ratio. Strategy games, chess, three-dimensional Tic-Tac-Toe, and Battleships were set up during the last week to provide the children with a final opportunity to play with their friends. The emphasis however was not on winning the game but on investigating the "game moves"—how the game worked—and trying out their ideas. Some children proved very adept at understanding the operation of the games and maximizing their chances of success.

The purpose of the final session was two-fold. It gave children the opportunity to interact socially with other children and play games of mutual interest, and also gave parents the opportunity to meet with one another and share ideas and concerns about their children.

Outcomes

A summary of our objectives indicated by this model is given in Figure 3. Some children gifted in mathematics or science may be relatively autonomous outside the classroom and involve themselves in open-ended problem solving. Many are tinkerers and seek to explore how devices work. In contrast, some have very narrow fixations such as an intense fascination with information about dinosaurs or astronomy or calculating large numbers and without having ever explored or even been aware of other domains of science or mathematics and the interrelationship of these subjects. At the end of the program, we found children more willing to engage in new endeavors and to share their interests with others. The program, through the approach described, attempted to support a transition from a situation where the child was often alone, isolated, and whose needs may not be accommodated to a situation that supports his or her optimal performance.

Opportunities for undertaking further exploration of ideas and following up open-ended projects were taken up by a number of children in several ways. Some children, for example Kathy, contributed a successful entry to the local science fair. A number of children joined a

Strand	Undeveloped State	Goal State
Expanding experiences	Narrow, esoteric, often more dependent on external influences particularly family.	Self selected experiences, intense, willing to share and use ideas in other contexts.
Cognitive apprenticeship	Focus is more on content and knowledge retention.	Repertoire of problem solving components and strategies for knowledge acquisition.
Cooperative groupings	Adult orientation, tend to work alone, overbearing, or deny use of skills and avoid intellectual engagement with age peers.	Work productively with peers, accept and show interest in others' ideas, value peer support.
Social environment	Environment imposed. Feelings of boredom or need to conform.	The environment is engaging, positive and challenging. Opportunities for control, negotiation and risk-taking.
Affective development	Egocentric, withdrawn, hyperactive, isolated, superiority feelings.	Accurate knowledge of self and others, confidence and reflectivity.
	Assimilation of information, little opportunity for creation of new knowledge, more inclined towards acceleration.	Generation and application of knowledge, novel meaningful problems.

Figure 3 *Desirable goals in the approach*

science club even though membership was usually restricted to older children. These children participated in a range of activities that permitted extended problem solving. Other children became engaged at home in developing a range of models, devices or followed up interests in a more creative and exploratory fashion.

Conclusion

Gifted children have little difficulty in mastering content knowledge; the challenge they seek is to integrate that knowledge by applying it to real problems. This was initiated in our approach by introducing small projects in which children reported on discrete undertakings. The structure in one sense has a focus on play, fantasy, and hypothetical situations but also introduces some of the rigor of scientific methodology. Thus, in this context, independence and autonomous involvement in knowledge generation develops. Involvement becomes external to the group and public, and affords risk-taking opportunities. Ownership of a problem stimulates their commitment to solving the problem, and with help, many of the children become engaged in long-term investigations. We encourage children to engage in external competitions as a mechanism to achieve independent research for intrinsic satisfaction. However, most important is that these children have opportunities to develop their giftedness through interaction with like-minded peers.

The activities that we have described developed spontaneously on many occasions as a response to individual children's interests. The program was dependent on the strategies implemented rather than the prescriptive details of the activities. As children tended to respond individually to activities, often only a couple of children would follow through on a particular task. The freedom to choose activities, to follow up individual interests, and to engage in longer term uninterrupted projects with the encouraging support of the teacher was crucial to the establishment of a community of learners. The characteristics of gifted children—persistence, motivation, rapid learning—made many of the activities easy to implement in this context. The introduction of such a program in a classroom or school would require support from volunteer parents and adequate resourcing to meet the needs of all children. In a regular classroom, the range of responses and levels of performances will be wide. The demands of many mainstream children will require a high degree of support in ways that are different to the gifted child. However, the faster learning abilities, and higher capacity for reasoning of gifted children require special and different support. The gifted child will perform differently: "Gifted and talented children are those who do things a little earlier, a little faster, a little better, and probably a little differently from most other children" (Ginsberg & Harrison, 1977). The challenge that confronts us is to be able to provide maximum opportunities and deliberate intervention for the benefit of all children.

About the Authors

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Section 3

Activity Centers

Activity Centers are autonomous areas in learning environments where children investigate aspects of their world. Peter Rillero describes activity series and activity centers in Chapter 4.

In Chapter 11, Ithel Jones describes how activity centers are used for teaching mathematics and science. She then presents her Workshop Approach for centers that developed from constructivist theories and uses a variety of types of centers to give children active learning experiences. Jones explains the teacher's role in activity centers and discusses scheduling and evaluation.

Maureen M. McMahon and Nancy W. Wiltz explain the role of play in children's learning. In Chapter 12, they explain how to use a series of activity centers to foster play and learn about scientific instruments and methods. The authors discuss their observations of children's interactions with scientific laboratory and literacy tools, and explain how play can be a basis for learning in other types of centers.

In Chapter 13, Leslie Irwin and Jophus Anamuah-Mensah explain the importance of process skills in education including classification, comparison, communication, inference, prediction, measurement, use of numbers, space/time relations, conclusions, and observation. They present activity centers on motion to assist children in learning important concepts and in developing their process skills.

Jodi DeSantis, in Chapter 14, "The Mysteries of Matter," presents detailed information about six activity centers for teaching children the properties of matter. The centers stress assessment of children's understanding, opportunities to explore and experiment, questions from the teacher or classmates to guide that exploration, and discussion to help children to modify their original hypotheses.

Chapter 11

The Workshop Approach: Using Learning Centers to Teach Science and Mathematics

Ithel Jones

The use of learning centers in the primary grades is generally recognized as an appropriate, effective, and efficient means of providing children with enrichment of subject areas, and an opportunity to explore and experience many different fields. Learning centers, or activity centers, have been used in numerous ways by individual teachers. Some, for example, use centers as the focus of all their classroom activities. Others use centers only during a certain time of the day. Some centers may be designed to focus on the acquisition of a specific skill or concept, whereas others may be more open ended. Such variation in how learning centers are used probably reflects the fact that there is not one "correct" way of using learning centers in the primary grades. On the other hand, learning centers describe a child-centered approach for creating meaningful learning contexts in the early grades.

In this chapter a "workshop" approach for using learning centers to teach science and mathematics is described. This workshop approach represents a specific configuration of learning centers designed to provide for the individual differences and needs within most classrooms. The chapter's first section presents an overview of the model as well as a theoretical rationale for using the workshop approach to teach science and mathematics in the early grades. Next, some suggestions and guidelines for planning and organizing the science and mathematics workshop are discussed. This is followed by a description of the learning environment and the teacher's role. The final section presents some suggestions for assessment and evaluation.

The Workshop Approach

The workshop approach is a model for organizing and using learning centers to teach science and mathematics in the primary grades. The approach is based on the principles of developmentally appropriate and constructivist learning practices (Bredekamp, 1987). One of the key characteristics of developmentally based primary programs is that the environment is designed to optimize concrete learning and enable children to explore a wide variety of objects and materials. Furthermore, children are given an opportunity to work within a variety of social configurations; alone, with one or two other children, in small groups, and in large group activities. Within such programs the teacher observes, records, and assesses child and group progress and, subsequently, bases instruction on this information. Such responsive and developmentally appropriate learning environments can be created by adopting the workshop model.

A teacher who uses the workshop approach to teach mathematics and science adopts a conceptual orientation to plan and organize the curriculum. This means that substantial time is devoted to concept development by allowing children to construct meanings in the context of physical situations. The goal of the workshop approach is to provide children with a number of meaningful experiences centered around the same general concepts. These experiences are organized as a set of learning centers or learning stations, all devoted to the development of understanding. For example, a teacher might plan five centers such as a problem solving center, exploration center, game center, application center, and teacher center (small group). All of the centers are related in the sense that they focus on a related concept or topic, such as studying plants in science or the addition of numbers in mathematics. For each workshop session the child chooses a different center, with the ultimate goal of providing children with a balanced set of experiences. The approach, therefore, provides an opportunity for small group instruction on a given concept, while at the same time providing further opportunities to explore, practice, and apply the same concept; a practice consistent with the principles of a constructive pedagogy.

The Constructivist Perspective

Current reform efforts in education are often based on a constructivist perspective. For example, the National Council for Teachers of Mathematics, in their standards and evaluation document (1989), emphasizes the importance of problem solving, concept development, and the construction of learner generated solutions. Similarly, the American Association for the Advancement of Science (1993) maintains that science teaching should focus on gaining understanding and making connections, rather than simply acquiring facts. Constructivism describes a way of learning in which the child actively engages with the environment and builds his or her own knowledge and understanding (DeVries & Kohlberg, 1990). It is a perspective on teaching and learning that challenges teachers to create environments where they and their children can think, explore, and learn in positive, meaningful ways.

Learning is viewed as an on-going and interactive process. Young children act upon, construct, modify, and organize their experiences so that they can make sense of their world. In turn, they relate their new information to what they already know and, in doing so, acquire understanding. That is, as children actively engage in the learning process by interacting with physical objects and peers, they construct knowledge. Throughout this process of interacting with information and experiences, children progress through a cycle of learning activities (Bredekamp & Rosegrant, 1992; N.A.E.Y.C., 1991), as illustrated in Figure 1. This cycle of learning experiences involves learners participating at various levels of awareness, exploration, inquiry, and utilization. Each learner is exposed to new events, concepts or objects at his or her level of awareness. Then, during exploration, learners are provided with opportunities to bring personal meaning to these events, concepts, and experiences. Later, children engage in a process of inquiry, thereby developing an understanding of events, concepts, and experiences. Finally, during utilization, children use their learning in new and different situations. Typically, movement through the learning cycle is recursive. That is, children revisit earlier experiences and information so as to strengthen their knowledge and facilitate movement to the next level.

The above perspective of active learning by children has many implications for both mathematics and science education. First, it suggests that teachers should create environments and learning contexts that allow children to become actively engaged in meaningful activities and experiences which provide a context for the development of mathematical and scientific thinking and reasoning abilities. Furthermore, the environment should be arranged to provide opportunities for children to cycle through the learning processes of awareness, exploration, inquiry, and utilization (Bredekamp & Rosegrant, 1992). Finally, the curriculum should be structured around concepts and concept development, and substantial time should be devoted to developing an understanding of concepts.

	What Children Do	What Teachers Do
Awareness	-Experience -Acquire and interest -Recognize broad parameters -Attend -Perceive	-Create the environment -Provide opportunities by introducing new objects, events -Invite interest by posing problem or question -Respond to child's interest or shared experience -Show interest, enthusiasm
Exploration	-Observe -Explore materials -Collect information -Discover -Create -Figure out components -Construct own understanding -Apply own rules -Create personal meaning -Represent own meaning	-Facilitate -Support and enhance exploration -Provide opportunities for active exploration -Extend play -Describe child's activity -Ask open-ended questions - "What else could you do?" -Respect child's thinking and rule systems
Inquiry	-Examine -Investigate -Propose explanation -Focus -Compare own thinking with that of others -Generalize -Relate to prior learning -Adjust to conventional rule systems	-Help children refine understanding -Guide children, focus attention -Ask more focused questions: "What else works like this?" "What happens if ...?" -Provide information when requested - "How do you spell...?" -Help children make connections.
Utilization	-Use the learning in many ways; learning becomes functional -Represent learning in various ways -Apply learning to new situations -Formulate new hypotheses and repeat cycle	-Create vehicles for application in real world -Help children apply learning to new situations -Provide meaningful situations in which to use learning

Figure 11.1 *Cycle of learning and teaching*
(Bredekamp & Rosegrant, 1992, p. 33)

Planning the Workshop

The workshop model can be used to provide children with learning experiences in both mathematics and science. The following four key assumptions serve as guidelines for planning the science and mathematics workshop:

- The mathematics and science curriculum should be conceptually organized.
- Children should be actively involved in science and mathematics activities.
- Emphasis should be placed on developing reasoning and thinking abilities.
- Emphasis should be placed on the application of mathematics and science.

The teacher's first task in planning the workshop, therefore, is to structure the curriculum around key concepts. For example, in planning a unit on plants the teacher identifies concepts such as: (a) seeds grow into plants; (b) there are many types of plants; (c) most plants make seeds; (d) many of the foods we eat are seeds. Similarly, in designing a mathematics unit on geometry and spatial sense the teacher might identify key concepts that focus on the identification and classification of 3-D shapes (cube, sphere, etc.) and the exploration and development of spatial relationships such as inside/outside, top/bottom, above/below.

Having specified the key concepts, the teacher then plans the centers that will be assembled in the classroom. This entails describing each activity and specifying the objectives, concepts, and skills of the activities. At this stage, the teacher also lists the resources needed for the activity as well as the procedures of the activity. The workshop should consist of a number of learning centers where the children can discover, explore, and develop new concepts. The teacher, therefore, creates a balanced set of experiences so that the children can progress from learning that is primarily exploratory to learning that is more goal directed. Each of the centers should address the same basic concepts but should vary in the sense that they provide different opportunities to explore, investigate, and utilize the learning. To facilitate this process it is suggested that teachers select one or more of each of the following types of learning centers:

Exploration Center (awareness and exploration)

The exploration learning center consists of activities and materials that will allow children to explore, discover, and build so as to enable them to construct their own understanding of the general concepts being developed. This center will contain a broad range of materials and many of the activities will be open-ended. The materials, however, should be limited to those that relate to the concepts being developed. Children who attend the exploration center should be provided with minimal instruction or guidance. They should, however, be encouraged to come up with a plan at the beginning of the session and also to report their findings upon completion of the activity. When children complete their various activities in the exploration center they can be directed to the reading and writing center (see below).

Game Center (exploration and inquiry)

This center consists of a game-like activity that provides practice on the key concepts. For example, the teacher might utilize one of the many commercially available computer programs that provide practice on specific mathematical skills. Alternatively, teachers can, with very little effort, create a board or card game that will provide adequate practice on science and mathematical skills and concepts.

Problem Solving Center (inquiry)

The problem solving center should be the central focus of the science and/or mathematics workshop. This is because problem solving should provide the context in which skills and

Science / Mathematics Workshop Plan

Topic: *Magnets and magnetism* **Grade:** 1 & 2

Key Concepts:

- Magnets pull some things but not others.
- Magnets pull through some materials.
- Magnets are strongest at each end.

Exploration Center

MATERIALS	ACTIVITY
Assorted magnets; tray of assorted iron/steel objects: paper clips, nails, keys, chains, bolts, screws, etc.; tray of non-iron/steel objects: wood, clay, card, paper, pencil, crayon, string, rubber bands, aluminum	1. Free exploration (What can you do with these materials?). 2. Find out how many of the objects the magnets will pull. 3. Can you find other objects that the magnets will pull.

Problem Solving Center 1

MATERIALS	ACTIVITY
Three or four different magnets; paper clips; nails; small washers	1. Which one is the strongest magnet? 2. Write and draw results in the science journal.

Problem Solving Center 2

MATERIALS	ACTIVITY
Magnets; paper clips, nails, washers, and bolts; card paper; aluminum; shoe box; thin wood; sand or dirt	1. Find out if the magnets will pick up paper clips that are covered with paper. Try card, wood, and aluminum. 2. Put nails, washers and bolts in the shoe box and cover with sand or dirt. Can you use the magnets to find the iron and steel objects? 3. Draw a picture and write about the findings in the science journal.

Teacher Center

MATERIALS	ACTIVITY
Paper clips; small nails; bits of steel wool; horseshoe magnets; bar magnets	1. Scatter bits of steel wool on the table. Children take turns to see if any of the steel is attracted to the curved part of the magnet. Next, they try the ends of the magnet. 2. Children take turns using the bar magnets to attract the steel wool. 3. Use the bar magnets to attract paper clips and small nails. Do both ends attract the same number of paper clips and small nails? Are any attracted to the middle of the magnet?

Box 1 *Workshop Plan for Magnets*

(Continued on next page.)

Game Center

MATERIALS	ACTIVITY
Cardboard box; pins, paper clips, and other small steel objects; magnet attached to a piece of string; small piece of wood (fishing pole)	1. Half fill the box with the assorted iron and steel objects. 2. Children take turns "fishing for the metal objects. First they predict how many objects they will catch, then they count out loud the number of objects they have pulled up.

Application Center

MATERIALS	ACTIVITY
Small magnets; card; glue; pieces of wood and other odds and ends	1. Design a refrigerator magnet. 2. Make a device that will help you to find small nails and pins on the floor near the workbench area.

Reading and Writing Center

MATERIALS	ACTIVITY
Selection of books on magnets and magnetism; paper and pencils; drawing paper	1. Select books to read. 2. Draw a picture and write about the activities and findings in the science journal.

Box 1 *Workshop Plan for magnets*

concepts are developed. This center will include activities such as investigations, exploration, experiments, and challenges.

Application Center (utilization)

This is where the teacher presents a real life application of the concept being taught, and where the children get to apply their learning in new situations. Here the children get to use the specific concepts and skills that they have learned about in the various centers.

Reading and Writing Center (communication)

Providing an opportunity for children to represent, discuss, read, write, and listen is considered a vital part of both science and mathematics (NCTM, 1989). The reading and writing center, therefore, is an area of the classroom where the children might keep a mathematics or science journal, write lists, create and illustrate a book about a specific topic, or read about a science or mathematics topic. Establishing a reading and writing center as a regular and on-going part of the science and mathematics program ensures that this important aspect of the science and mathematics program is not overlooked.

Creative Center (utilization and communication)

The purpose of this center is to provide an opportunity for the children to express their scientific and mathematical ideas in a creative manner. Essentially, the arts are a means of thinking, learning, and communicating and, consequently, they complement other areas of the curriculum such as mathematics and science. For example, a child might use geometric shapes that he or she has used in the exploration center to create a pattern using scraps of materials. Similarly, as part of a unit on plants and seeds the children create a collage using various seeds. This center should contain materials such as paints, coloring pencils, colored paper, crayons, chalk, material, yarns, and other odds and ends.

Teacher Center (small group: communication, inquiry, and utilization)

The purpose of this center is to provide an opportunity for the teacher to interact with a small group of children. Here, the teacher selects activities that facilitate teaching and reinforces the key concepts being developed.

The actual number of learning centers utilized will depend on a number of factors including the number of children in the class, the size of the classroom, the availability of resources, as well as the nature of the specific concepts being taught. However, a minimum of four or five centers are necessary in order to provide a balanced set of experiences for the children. The following example of a teacher's plans might be helpful in illustrating how to organize and plan for a workshop approach.

In the example of a teacher's plans for a science workshop on magnets and magnetism, three key concepts and seven learning centers are outlined (see Box 1). Here, the teacher has planned activities to address the same concepts as well as to provide a variety of experiences for the children.

The Learning Environment and the Teachers' Role

Changing the room to accommodate a workshop approach takes considerable thought and careful planning. The teacher's first task is to prepare the learning materials and collect the resources for the center. Next, the centers have to be arranged in the classroom. Given the variation in classroom size, space, teacher preferences, and child interest, there is not one correct way of arranging learning centers in the classroom. Typically, the centers are arranged around the room, but they do not necessarily need to be physically separated from each other. Possibly of greater importance, centers are arranged so as to capitalize on the classroom environment's potential as a central force in stimulating intellectual activity. This means creating an environment that communicates a sense of adventure and excitement, is dynamic and changing and, at the same time, aesthetically satisfying.

Planning the physical environment for a workshop approach entails deciding where the areas shall be created, what to place in each area, what display space can be created, and how these display spaces can be used. The classroom environment should be well organized so that children know where things are and how to maintain their learning area. Thus, the classroom should be organized into distinct activity areas with clarity and logic. These learning areas can either be defined by physical boundaries such as bookcases or dividers or by more abstract boundaries such as a wall display.

Scheduling

Once the learning centers have been established in the classroom, the teacher decides how individual centers will be utilized by each child. Thus, a schedule for effective use of the centers has to be carefully developed. It is important that the children know exactly what is expected of them, what they are doing, and when they will be doing it. One option is to post a master chart in the classroom listing names of children under the centers where they will work during that session. An alternative is to allow the children to select their own activities. To facilitate this process the workshop session begins with a circle meeting during which the options for the session are listed on a large board. The children then, in turn, select an activity by placing a colored tag or clothes pin next to where they will be working.

Teacher's Role

The most important component of the science and mathematics workshop is the probable interaction between the teacher and his or her children. The primary role of the teacher during the workshop is to facilitate learning and promote creative thinking, problem solving, and decision making. The teacher, therefore, stimulates intellectual activity and fosters the development of thinking by engaging children in experiences that encourage inquiry, representation, and reflection. Clearly, the way the teacher presents materials and plans the learning activities is critical here. Beyond this, however, how children come to understand the various concepts and the development of their thinking is governed by the nature of the interaction between adult and child.

In order to make the learning experiences meaningful for the children the teacher should create opportunities to interact with individual children, small groups, as well as large groups. Large group activities are essentially used as a means to begin and end the workshop sessions. For example, the workshop could begin with a brief large group meeting during which the teacher communicates what is expected of the children. This initial meeting can also be used as a mini-lesson to address a particular concept or skill. Similarly, the workshop might end with a large group meeting during which children are invited to share their findings with the class, show something they made or, perhaps, report on how they used the materials at a specific center. The teacher, in turn inquires about the children's understanding of the concepts and poses questions that encourages reflective thinking.

Children can come to change or reinforce their conceptions by engaging in dialogue both with the teacher and one another. Therefore, as the children are working at the various centers the teacher should interact with a small groups or individual children. As the teacher circulates among the various learning centers, thoughtful, open-ended questions are asked to encourage child inquiry. Such an approach provides an ideal opportunity for teachers to observe and assess children's progress as they function in their regular settings.

Assessment and evaluation

The science and mathematics workshop approach allows teachers to focus on the needs of individual children. This basic orientation is a key characteristic of developmental education whereby the instruction is based upon information that teachers collect through systematic observation and assessment of individual and group progress (Bredekamp & Rosegrant, 1992). Indeed, observation and assessment is critical in implementing and maintaining the science and mathematics workshop. Careful assessment and record keeping allow the teacher to focus on what each child can do and to plan activities and experiences that will help each child progress. In short, assessment and evaluation should be an integral part of workshop decision-making.

The workshop approach provides an ideal opportunity to embed assessment and evaluation; during the workshop teachers can collect authentic assessment evidence. In turn, this information can be used to determine what individual children can do as well as to make informed instructional decisions and set learning goals. The relevant information to facilitate this process can be collected during the workshop sessions through observation of process, observation of product, and during conversations with individuals and groups of children.

The science and mathematics workshop allows children to engage in a number of different activities which, in turn, provide multiple opportunities and contexts for children to demonstrate what they know. This allows the teacher to observe children thoughtfully and systematically within the natural setting of the classroom as they interact with both their peers and materials. Teachers can also examine how children represent their thinking by observing products such as drawings, paintings, constructions, writings, graphs, charts, and other products. Finally, during conferences and conversations with individuals and groups of children, the teacher can obtain valuable insight into their thinking.

Information collected through observation should be recorded in a manner that will enable teachers to discover patterns and assess individual progress. Three basic approaches are recommended here. Checklists are useful for recording information about student learning as well as to record individual participation in the various workshop activities. Rating scales can be used to record judgments about individual performance and learning outcomes. Finally, anecdotal records, representing a comprehensive source of assessment, can be used to record rich descriptions of children's behavior.

Summary

The science and mathematics workshop approach is a method of organizing learning centers in developmentally based primary programs. The approach centers on providing a series of meaningful experiences around core science and mathematics concepts. These experiences are presented in the form of learning stations or activity centers that add to the richness of the classroom and provide flexibility for both children and teachers to pursue meaningful activities.

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Chapter 12

Emerging Scientific Literacy Through Play

Maureen M. McMahon & Nancy W. Wiltz

This chapter offers the early childhood practitioner both a theoretical base and practical methods for achieving scientific literacy through play. The chapter opens with a theoretical rationale for the integrated role of play in the education of young children. Definitions of play and play's function in enhancing children's optimal development are followed by brief discussions of emerging literacy and scientific literacy. Literacy centers are explored as avenues for meaningful learning opportunities. Through the specific pursuit of scientific literacy in an early childhood setting, teachers are exposed to a unique approach whereby children's play is integrated with their emerging scientific knowledge.

In the second section, we use a six-week emerging scientific literacy project to organize a general framework for an instructional play-centered environment where children's actions and dialogue become evidence of their learning. This model, which integrates science and play, is based on a research study where young children were exposed to the laboratory tools of science, first in the housekeeping corner, then a literacy center. The story of this research includes details of the literacy integration and subsequent changes in the children's perceptions of science in their world. The narrative begins with children's exposure to scientific laboratory and literacy tools and continues as the tools are moved to a scientific literacy play center, where children play, interact, and experiment. Following a hands-on production of silly putty by the children in the scientific literacy center setting, observations of changes in children's dramatic play, their scientific knowledge base, and their discourse are discussed.

The final section (Appendix) suggests four other unit topics appropriate for a scientific literacy center in a preschool classroom. These units are aimed to include science in a sample of content domains: physics, health, environmental science, and earth science. Furthermore, these units are ones that can be easily integrated with language arts, reading readiness, mathematics, and social studies by the early childhood teacher. Play theory is implicit in each of the units.

Play is More than Fun and Games

Play is a phenomenon that has fascinated teachers, educators, psychologists, and philosophers for decades. Although there are schools and programs that do not include play as part of the curriculum, most early childhood educators include play activities as critical elements in the educational development of young children. Definitions and theories of play emphasize the belief that play is an important activity for young children.

Defining Play

Play is a natural activity of children but, as a concept, can be difficult to understand. Play, while identifiable, can appear in so many forms that it is difficult to decide at any given moment whether a particular activity is play or not. Western culture's perceptions of play have been significantly influenced by attitudes about what play is not. Helen Schwartzman (1978) defines play in these terms: "Play is not work; play is not real. Play is not serious; play is not productive....Work can be playful while sometimes play can be experienced as work" (pp. 4-5). While Joe Frost and Barry Klein (1979) think play should be fun, active, spontaneous, free, unconstrained, self-initiated, and natural, it is the seriousness and intensity of play that provides children with a primary path of learning during childhood. Kenneth Rubin, Greta Fein, and Brian Vandenberg (1983) identify play's major characteristics as being actively involving, intrinsically motivating, process rather than product oriented, non-literal, free from external rules, and self-referenced rather than object-referenced. Schwartzman (1978) states that play provides children with opportunities to learn, imitate, and practice culturally appropriate adult roles while Gracey (1975) proposes that during play time some children learn to create their own worlds within the adult imposed physical and social world of school. Play's value as a socializing mechanism and as a communicative process challenges the traditional American Puritan work ethic that play is a frivolous, useless activity. Play is a joyful, lived experience!

Importance of Play in Early Childhood Classrooms

From a developmental perspective, play is the most universal activity of children, providing them with a way to explore, invent, and test a full range of possibilities. There is no assigned or expected product. One cannot fail. Play helps children construct ideas about the relationship of objects by adjusting the existing framework to accommodate new information. Constructivist theory, rooted in the work of Jean Piaget (1962), allows children to construct their knowledge through the process of equilibration. This process is made up of two complementary processes: assimilation and accommodation. In assimilation, children acquire information from their environment and incorporate it into their existing schema or their sense of understanding. If new information cannot fit into or is in conflict with the existing framework, change must occur. Children revise their systems of knowledge through accommodation. The result is a balance of existing and new knowledge equilibrium. Play is one way that children take information from the outside world and adjust it to their already developed schema of understanding. The flexibility experienced in play encourages children to solve problems, test hypotheses, verify outcomes, make predictions, reconstruct ideas, estimate outcomes, and reason about cause and effect.

Vygotsky (1978) assumes that children are social beings from birth and emphasizes the importance of the socio-cultural context of life. According to Vygotsky, the acquisition of knowledge is always socially mediated, both by the goals of the larger culture and through social interactions between individuals, specifically, between children and more experienced partners. Therefore, play provides a more socially oriented approach to cognitive development. While Piaget concentrates more on the nature of cognitive processes and the stages of these structures, Vygotsky focuses more on the social events that lead to practical activities. Vygotsky sees social development as resulting from children's pragmatic experiences in real life. Like Vygotsky, George Herbert Mead (1934) asserts that all knowledge is acquired in a social context. Cognition develops through interactions between children and their environment. Social knowledge and the ability to act on that knowledge results in conversations between individuals which takes place in a social context. Like Vygotsky, Mead emphasizes the importance of perspective taking through peer interaction.

If it is play that stretches children's cognitive ability, then it is optimal for development. Therefore, most early childhood educators endorse appropriate and challenging play opportunities. When children are provided a wealth of experiences that support curiosity, exploration, and divergent thinking, they begin to understand concepts such as transformation, conservation, cause and effect, spatial-time relationships, measurement, categorization, seriation, classification, and prediction. Children need to be encouraged to explore a rich array of activities, objects, and people, to exercise their natural curiosity. They need to experiment with materials that help them learn to observe and explore objects, their actions and interactions. Play, as a socializing mechanism, aids in the communicative process, which includes listening to, watching, reflecting on, and gaining insight. Play is an activity that allows young children to repeat experiences and to understand them more completely. In play, children express ideas for which they have no words. In symbolic play, children bridge the gap between reality and fantasy. Through role-playing, children clarify perceptions of themselves and others. Play serves as a way for children to express ideas and feelings, explore understanding, and build social relationships.

The teacher's role in facilitating play is to create a general climate where play is accepted and encouraged. Skills in watching, listening, and observing children help teachers understand how children participate in an experience as a participant, as an observer, or as a recipient. Teachers need to know what children bring to the experience, how the experience is structured and whether children can make sense of it. Therefore, teachers who value the well-rounded development of young children provide ample time and space for play, select relevant play activities, provide necessary materials and equipment for play, and encourage positive social relationships that help children extend their play in meaningful ways.

Facets of Literacy

Emerging Literacy

Literacy is the condition or quality of becoming proficient in oral and written language. Literacy learning of oral and written language begins in infancy and develops gradually. While it is unlikely that preschool children learn to read and write in the conventional sense (Hall, 1991), when children play with sounds, when they learn the rules of taking turns in conversation, when they are exposed to print, when they plan story lines, when they experiment with the forms and functions of language, the foundations of literacy are built. Vygotsky (1967) asserts that play is helpful in the development of language and thought because play with signs and tools helps children form mental structures which frees them from the constraints of the real world. Play with meaning, as well as objects, gives children the opportunity to engage in higher-order thought processes. Play experiences with literacy-related resources, then, provide opportunities for children to explore literacy in naturally occurring situations where they can elaborate and extend their play into new contexts, incorporate new information, and, in turn, enrich their lives. There are powerful links between play, literacy, and learning.

Scientific Literacy

An integrated play curriculum provides a unique opportunity for teachers to furnish young children with scientific literary explorations. As children play, they are actively engaged in the many processes the scientific community labels "science." Yet these activities do not have to be structured, prescribed "experiments." Structured types of activities are often an important part of the early childhood curriculum, but "these activities are not necessarily children's play nor are they necessarily based upon children's own expressed interests" (Van Hoorn, Nourot, Scales, & Alward, 1993, p. 97). Providing children time to play with traditional scientific equipment allows them freedom to explore the possibilities of the materials centered around their own ideas, interests, and limited only by the boundaries of their imaginations. When this play is later enhanced with traditional scientific labels such as "scientist," "thermometer," "beaker," and "graduated cylinder" and coupled with scientific processes such as testing, measuring, experimenting, and investigating, children begin to grow in their scientific literacy.

But what does scientific literacy really mean in an early childhood classroom? Scientific literacy is an often illusive term in the field of science education. Both science education researchers and science classroom teachers struggle daily to identify the instructional practices that best promote scientific literacy. The scientific community is concerned about the need to improve the scientific literacy of students and the general public. But, what is scientific literacy? Although scientific literacy has many of the characteristics of an educational slogan (Roberts, 1983), Bingle and Gaskell find "there is substantial agreement that the most important aspects of scientific literacy are those that impinge on everyday life, in particular those which develop the knowledge and skills needed to make decisions and solve problems where science, technology, and society interface" (Bingle & Gaskell, 1994, p. 86). Prominent science education national curriculum reform efforts in the United States today, the American Association for the Advancement of Science's (AAAS) Project 2061 and the National Science Teacher Association's (NSTA) Scope, Sequence, and Coordination also have *Scientific Literacy for all Americans* as their fundamental focus. These curricular frameworks argue that achieving scientific literacy is much more than having the ability to recall mere facts and figures and gaining knowledge of scientific content and rudimentary formulas. The quest toward scientific literacy includes the journey into understanding how a scientist does his or her work, the philosophy of scientific thinking, and the interface between science and society. Other integral components of scientific literacy include limitations of scientific findings, problem solving and making decisions based on a scientific knowledge base, and the potential to view science as an integral part of one's personal existence as well as part of the global society (AAAS, 1989, 1993; NSTA, 1992).

Scientific literacy in a play-centered early childhood classroom also supports the journey towards understanding how a scientist does his or her work. Just as children play with parents, teachers, and friends in a housekeeping area with all the clothes, equipment, and associated vocabulary, so should they have the opportunity to play scientist, laboratory technician, doctor, airplane pilot, zoologist, or landscaper. Through play, children should have the opportunity to experience numerous ways the scientific world touches their lives.

Literacy Centers

Learning centers have become one popular, developmentally appropriate technique designed to meet the needs of children in preschool through primary grade classrooms. Center-organized classrooms "allow active and purposeful construction of the learning environment by adults in order to promote the development of useful skills and abilities in children" (Kostelnik, Soderman, & Whiren, p. 294). Learning centers provide flexible, adaptable activities as an effective means to facilitate indirect learning in the classroom. Centers are organized to insure one-on-one, teacher-to-child interactions, as well as children's noncompetitive interactions with each other in small groups. Learning centers provide children with the freedom to move around the room, accept responsibility, develop respect for themselves and others, think for themselves, express their feelings, empathize with others, and solve problems without fear of criticism or repression. Furthermore, centers provide for children's diverse interests, differing attention spans, and developmental differences.

Literacy centers provide meaningful literacy-oriented activities in which reading and writing occur, such as story book corners, listening stations, and writing centers. Unit or "core" centers (McKee, 1990) can be used as places where children regularly examine, touch, taste, smell, and experiment with materials that may be a part of an ongoing thematic, science, social studies, or current event unit. "Core" centers are on-going classroom spaces that often include a language arts center, a creative arts center, a science/exploration table, a mathematics/manipulatives table, a game table, a block area, and a pretend play area. "Special interest" centers may also be set up for a shorter duration of time to allow for the occurrence of free-play with special equipment. Used in each of these ways, centers provide opportunities for children to explore concepts over time in an integrated manner. Inclusion of visuals such as symbols, posters, books, and photographs, many of which include written language, is encouraged.

Science Literacy Play Centers

Science literacy play centers offer young children the strengths of a literacy center while capturing the creative freedom of play. Children are exposed to an organized grouping of science materials, equipment, and clothing in a setting where the only expectation of them is to play freely with the offerings. The children can play quietly alone with the materials or engage in a complex role-play with their peers. Based solely on their imaginations children create a pretend micro-world around the science materials and equipment they have never seen before. This is not to say that young children do not know or have never experienced "science" before; the world of a child is full of science! However, it is clear that children do not hold a formal understanding of the science in their everyday world. Although they can tell us about weather, seasons, health, animals, and plants, they rarely recognize any of these as "science" related. Science as a concept is new and foreign to them. The science literacy play center is a place where the events of everyday life and a more organized notion of "science" are encouraged to link together through play. Children experience the curiosity, joy, and excitement of the materials and equipment found in the center while simultaneously learning that these objects and items are related to "science." The sparks of interest, understanding, and positive attributes are kindled and linked to the concept of science. These initial values, habits of mind, concepts, and beliefs are a wonderful foundation for science literacy.

Creating a Science Literacy Play Center in Your Classroom

As one considers the daunting task of first attempting to incorporate a science literacy center in your classroom, a thoughtful plan may be helpful. While all teachers are unique and should tailor their instruction to utilize their many personal teaching strengths, nonetheless, a general framework or model may provide a sound beginning for creating a science literacy center for the first time. The reading adventure that follows allows you to experience a 6-week science literacy center general model from an organizational, instructional, play-centered point of view. Teacher tasks that were accomplished each week and real world vignettes, incorporating young children's actions and dialogue, are included. Moreover, a checklist of literacy explorations are offered as suggestions for use in your observations of the children during free-play time at the center.

Week 1

Teacher Organizational Tasks

- Place chosen play clothing, science materials, and equipment in an accepted free-play area in your classroom. Do not provide any introduction to the new offerings.

  Please note: For the purposes of this section the new science play clothing, materials, and equipment list for the creation of an exemplar science literacy center is as follows: 3 pairs goggles, 3 aprons, 1 flask, 2 graduated cylinders, 6 beakers, 1 funnel, 20 test tubes, 1 test tube rack, 1 lb. red kidney beans. All of the lab equipment is plastic. Other science literacy center ideas are provided in the appendix.
- Plan to observe as the children use the clothing and materials in a way similar to how they would use clothing and manipulatives found in any housekeeping, block, or other free-play area. Watch as the children integrate the new offerings into their previously created play environments and worlds.

Real World Vignette

Most children will immediately be drawn to anything that is new in a familiar play setting. If goggles, aprons, and laboratory equipment are suddenly found in the housekeeping area, children's curiosity will lead them to investigate. They will try on new clothes and experiment with any new "toys." After the initial inquiry-discovery time with the new materials, children's behaviors will diverge. Some children, often the higher players, will begin to integrate the new artifacts into the old stable play setting.

Sam: You should make me dinner. I'll be home right away after work.

Julia: I'm making your favorite. I'm making hamburgers and spaghetti.

Sam: Good, I'll be very hungry when I get home.

Julia and Sam are four-year-olds in a preschool setting. As Julia speaks to Sam, she stirs a pretend mixture in a pot on the stove in the housekeeping area. Although spoons are available, Julia uses a graduated cylinder as a stirring utensil. She integrates the graduated cylinder, a science tool, into her understanding of the play world of housekeeping. The cylinder has no meaning to Julia other than its obvious use as a cooking utensil. In a similar way, beakers become cups, bowls, or pots; goggles are used so that hot foods do not splash in your eyes; and lab aprons take on their natural household counterpart protective apron role.

Other children shy away from integration of new materials into already established play centers. They often avoid the use of the new materials. After seeing some children avoid the new equipment for days, they were asked, "Why aren't you playing with this equipment (goggles, test tubes, cylinders, flasks, beakers) in the housekeeping area?" Some of the children's common responses were:

John: I don't know what it's for.

Tyra: That stuff doesn't belong here.

Leon: That's not toys you use in a house.

Similar reactions from children occur when the science materials are put in other free-play areas in the classroom. There are children who are drawn to the integration of the new materials and others who refrain from enlarging their view of the play area to include something untried and not yet understood. Observation of children during play can begin to tell teachers much about ways individuals understand and interact with their world.

Checklist of Literacy Explorations

- Document highlights of the children's actions and play themes while observing them during free play. Try and note the differences in how the children interact with the new science materials when they are placed in familiar play settings.
- Document the different ways in which children integrate the new science materials into the familiar play settings.

Week 2

Teacher Organizational Tasks

- Allow the play clothing, science materials, and equipment to remain in the selected free-play area with no additional introductions or explanations.
- Plan to observe the children's continued interaction with the new offerings and the dialogue associated around the play with the new equipment and materials.

Real World Vignette

Laura:	I'm cooking something really special. Do you want to add any magic to it? (Laura stirs a pretend mixture in a beaker that she is using as a pot on the stove.)
Francesca:	Let's put special juices and spices in our soup. (Francesca pours pretend juices and spices from test tubes into the beaker.)
Laura:	Don't add any more things. You'll ruin the soup if you add too much. I'll finish it now; you get the dishes out.

These four-year-old girls are playing in the housekeeping area of a preschool classroom. Laura and Francesca often engage in high-level dramatic play. Their dialogue illustrates that they have chosen to incorporate the new science equipment into their usual housekeeping role-play setting. Laura and Francesca have assigned domestic roles to unfamiliar scientific equipment so as to integrate them into their dramatic play. The housekeeping theme is preserved as the new materials are used in traditional cooking roles.

Some children find difficulty in the integration of the new materials and equipment with the old, even after a two week time period. With the total unfamiliarity of the new objects and limited-to-non-existent relationship of the new objects to the play setting or the children's everyday world, many children choose to avoid the incorporation of the unfamiliar into their play. Through observation of the children's play, one learns to gauge the level of comfort and risk each child has with respect to the unknown.

Checklist of Literacy Explorations

- Try to recognize common play themes between individual children. Listen and observe closely. If you take the time, you will learn a lot about your students' vocabulary and understanding, communication strengths, and social interaction through their play.
- Gather details describing how children's play has changed with the new materials and equipment over the initial two week time period.

Week 3

Teacher Organizational Tasks

- Move the play clothing, science materials, and equipment to a new location and establish a new center in your classroom. Refrain from calling it a "science" center. Establish the center as a new free-play area.
- Plan to observe and document the children's play in this newly established center within your classroom. Try to capture the play themes and how they may have changed since the new offerings were moved from a familiar play center to a new environment with limited history and context.
- Plan to conduct informal conversations and interviews with the children about the nature of the new materials and how they choose to play in the new center. Listen as they talk about their life at school.

Real World Vignette

The movement of the new science materials and equipment from a familiar play setting to their own center usually evokes a change in children's behavior and play. Certainly, some of the more cautious children will continue to abstain from interaction with the new materials. However, as the new materials and equipment become the focus of a center all their own, children may flock to play at this new center. Unlike the play during weeks 1 and 2, where the children felt a need to integrate the new with the old, now children are free to play with these objects, clothing, and equipment in any way they choose.

Joshua: We're mad scientists! (Joshua begins to pour beans from a beaker through a funnel into a graduated cylinder.)

Rebecca: I'm putting my apron on. I'm gonna help you.

Laura: Aren't you going to help us make "power"? (Laura swirls a few beans violently in a flask.)

Rebecca: Yeah. What if they find our hideout?

Joshua: Look at my super poison! (Joshua excitedly holds up a single test tube full of beans.)

Laura: C'mon, aren't you going to play monsters with us? (Laura asks this question of the other four children at the table who have yet to join in the "Mad Scientist" play theme.)

This play dialogue erupted almost instantly after the new science literacy center was opened as a free-play choice in the Kindergarten classroom. Seven children immediately ran to the center and began selecting items as their play "toys." On this occasion, the center was stocked with all of the same offerings that were available during the prior two weeks in the housekeeping area. Now that the new items were no longer linked to a housekeeping context, the children began inventing original roles for the equipment and materials. The "Mad Scientist" theme, originated by Joshua, was enriched and supported through the play of Laura and Rebecca. Eventually, it grew into a "Monster" theme whereupon more children actively participated.

Although these children were drawn to the new center and flourished there through their personal creativity and imagination, other children seemed to need more time and modeling before they actively play at the new center. In this next dialogue, an intricate play scenario unfolds between Alejandro and Ryan, two 5-year-olds in a Kindergarten setting. One of their playmates, Nikki, is only somewhat engaged in the play theme.

Alejandro: We're making chocolate ice cream with hot lava in it. (Alejandro stirs a beaker full of beans.)

Ryan: Let's eat it all.

Alejandro: This makes me a good guy. Here Nikki, you drink some of this potion too. (Alejandro offers Nikki a test tube full of beans.)

Nikki: (Nikki is putting beans into test tubes and setting them in the test tube rack. She does not acknowledge Alejandro's offer.)

Ryan: That's the poison; don't let her take that! Here Nikki, you drink this magic potion that I made for you.

Nikki: (Nikki continues to play with the test tubes and the beans quietly. She watches Ryan and Alejandro closely, but does not enter into their play scenario.)

No two children are exactly alike. They are individuals and experience the world differently from one another. Nikki is content to play quietly by herself with the new equipment while remaining somewhat a member of the play group through her proximity to the action. Nikki is cautious, yet very interested in playing with the new "toys."

Moving from observations of the children to informal interviews, a more detailed understanding of the child's world is uncovered. Clearly, the children have had no prior contact with any of the new materials or equipment. They perceive the science objects to be simply toys similar to any other playthings present in their classroom.

Teacher: What are you doing at this new center?

Chad: We're just playing.

Myra: Yeah, we're playing.

Teacher: Have you ever seen these kind of materials or equipment before?

Chad: No.

Myra: We got to play with them when they were over there (points to the housekeeping center) last week.

Teacher: Do you have any of these "toys" at home?

Chad: No.

Myra: No, I know I don't have any of these toys at home.

As the informal questioning continued, the teacher asks the children about other things they do at school. Questions were asked to uncover children's prior scientific knowledge. The next dialogue showcases a common set of responses from the children.

Teacher: Other than playing, could you tell me about some of the other things you do here at school.

Chad: We read, write, paint...

Myra: ...and we draw and color and do puzzles...and make things...

Teacher: Do you ever do math at school?

Chad: No.

Myra: No, not really.

Teacher: How about science? Do you ever do science at school?

Chad: No, we don't do science here.

Myra: I really don't know what that is.

Teacher: What do you think science is?

Chad: I'm not sure.

Myra: I think it's a lot like painting and drawing and stuff like that.

These children have no formal understanding of the somewhat abstract notion of science. This is not to say that they do not have a very complex understanding of their world and all that it is made of, but, they have not yet linked this personal experiential knowledge with any greater concept or understanding. Nor have they yet made connections between the everyday science of weather or health to a more formalized large concept of "science." It is important as a teacher to understand that very young children have a great many experiences that make up a rich knowledge base, but these experiences are individual in nature and not linked to other experiences. Educators, are often the first people other than children's parents, to support the connections between personal experiences and forming greater concepts or knowledge chunks.

Checklist of Literacy Explorations

- Document the major play themes and interactions with the science "toys" now that they have been placed in the new center.
- Document the children's ideas and feelings about school and what they do there. Try to capture an understanding of their beliefs about play and other school activities.

Week 4

Teacher Organizational Tasks

- Introduce pictures and names of the new equipment into the new play center. Many teachers have seen great success introducing words and pictures into a play center by laminating them to card stock to assure their durability over time.
- Introduce other traditional literacy materials (e.g., logbooks, sketch paper, graph paper, pencils, pens, markers, etc.) into the new play center.
- Plan to observe the interaction of the children with the new pictures, words, and other associated traditional literacy materials.

Real World Vignette

Pictures, vocabulary, and logbooks were introduced into the new center. Researchers took time to chat with the children who chose to play at the center. The children were shown placards with the pictures and terms and told that these were pictures and words to describe the new science equipment and materials. This was not used as an opportunity to "teach" for that would have violated the "play" atmosphere previously established for the new center. The children were simply alerted to the relevance and related nature of these traditional literacy materials with the science equipment and materials.

All of the children viewed the pictures and associated words, but seemed to find no interest in doing much with them. A few children passed out the placards as they would deal cards from a deck of playing cards. After minimal interaction with the pictures and words, these items were set aside and the children refocused on playing with the science equipment and materials. After a few days, some of the children chose to revisit the placards after discovering the logbooks. A few children copied the words and pictures from the placards into the logbooks.

Teacher: What are you doing today Kelsey?

Kelsey: I'm writing in my journal. I need to write all of the names of this stuff in my journal.

No one told Kelsey that the logbook was a journal or that he should enter any information into it. Kelsey made these connections based on his past experiences in his classroom. Kelsey chose to incorporate this journaling experience into his play. After watching Kelsey, a few other students began to write or draw, both in the logbooks and on available drawing paper. Most students continued to interact with the placards simply by viewing them and setting them aside.

Regardless of the duration or kind of interaction with the traditional literacy materials, it is a needed step in establishing a science literacy center. Offering the children words, pictures, and materials often associated with serious learning during play allows them the freedom to interact with the offerings in individualized ways. Teacher observation during this week offers opportunities to see children's reactions to traditional literacy materials in a play setting. Children's comfort, familiarity, and interest in these materials through their play actions and dialogue are things to look for during this observation time.

Checklist of Literacy Explorations

- Document the children's interaction with the traditional literacy materials. Compare these interactions with the children's interactions to similar materials during non-play activities in the classroom.
- Capture dialogue that helps explain how children are personally relating to these traditional literacy materials.

Week 5

Teacher Organizational Tasks

- Prepare and deliver a directed science experience in small groups with the science materials and target pictures and vocabulary. The directed experience consists of a guided activity where silly putty is made with the children. As the activity is conducted, all equipment is named, and placards with pictures and terms are used. The guided experience is bespeckled with short anecdotes of what it means to be a scientist, i.e., what they do, how they conduct research, what they read and write.
- Plan to capture the guided science experience on video tape. Teachers have had much success setting up a tripod and allowing the video tape to run freely throughout the activity.
- Plan to observe how children's play changes after the directed science experience. Allow all of the science and traditional literacy materials to remain in the science literacy play center.

Real World Vignette

Take time to select and prepare a guided science experience with small groups of children that uses all of the equipment and materials you have been using in your science literacy center. The objective is to provide a rich context in which to seat the use of the science objects. The children should be given an experience that allows them to see, hear, and experience a microworld sketch of a scientist and their professional world. Take time to revisit the naming of all of the equipment and materials. Discuss how a scientist would use each of the tools while allowing the children to use the tools in the hands-on activity. Highlight the use of safety equipment as you outfit each child with goggles and apron.

Teacher: Let's all take a beaker and get ready to begin the experiment. (This is said to a group a five children after the teacher has reviewed the names and uses of all of the laboratory equipment using the picture placards.)

Jon: Which one? The tall one or the short one?

Anita: The short one that looks like the cup. The tall one's a cylinder.

The instruction during the guided activity is warm and casual, yet structured. Questions, excitement, eagerness, and exploration should be encouraged. As much as possible, the children should see this activity as an extension of their play in the science literacy center.

Tyrone: When I put these goggles on I'm the leader of all the other scientists.

Hugh: Goggles don't make you the leader.... We all have to wear these so that junk don't get in our eyes. Scientists don't want junk in their eyes.

Tyrone:	Grab your beaker cause it's time to make magic!
Teacher:	Now, I would like each of you to fill your beaker to the 20 milliliter mark with glue. Everyone put their finger on the 20...the 20 milliliter mark on your beaker.
Tyrone:	Let's get going.... When's it gonna turn into something?

The excitement and enthusiasm of Tyrone is exemplified in this dialogue. Interestingly, he incorporates the new names of the equipment with his play theme of magic and being leader of the scientists. In addition, he uses additional knowledge from his personal life that supports the anticipation that during this activity something special will be created. At this point in the activity the children are not aware that they are producing a silly putty type product. As a teacher, being open to all of this high energy excitement and child-generated ideas allows this initial learning experience with a formal notion of "science" and "scientists" to be extremely positive.

Checklist of Literacy Explorations

- Capture the guided science experience on videotape for teacher review. Upon review of the tape, notice interesting and unique actions and dialogue from the children. Children's individual reactions to the guided science experience provide indications about their general interest and intrigue in this area. Early interest and early anxiety is often able to be seen on these videotapes.
- Document the changes in children's play in the science literacy center following the guided science experience. Try to note whether children are using any of the information given them during the guided activity.

Week 6

Teacher Organizational Tasks

- Allow all science clothing, materials, equipment, words, pictures, etc. to remain in the center for continued free-play.
- Continue to observe how children's play changes after the directed science experience. Watch closely for inclusion of terms, thoughts, or actions introduced during the guided experience.
- Plan to informally interview the children about the guided science experience and their feelings about the new center and "science."

Real World Vignette

Lauren:	You have to put on your goggles if you're gonna play at this table. (Lauren announces this to three children at the table as she joins and puts on a pair of goggles.)
Tracey:	I need my goggles on to protect my eyes from sharp stuff. (Tracey joins the group and immediately puts on goggles.)
Lauren:	Let's make potions.
Tracey:	I'm making poison ivy balls...volcanoes...and bombs.... (Tracey pours beans from a beaker through a funnel into individual test tubes.)
Lauren:	My potion! My beautiful potion! (Lauren holds up test tubes full of beans.)

Tracey: Give me those test tubes. Fire, lava, bombs! You guys gotta get some of this stuff! I'm selling this stuff.

Through this dialogue, a mixture of actions and talk from the children's early play themes in the science literacy center are combined with the use of correct terminology for some of the equipment and a correct understanding of the use of goggles. This mix of actions and dialogue from various aspects of the children's knowledge base was common among the children. The guided experience seemed to offer the children more detail as well as a context in which to place the science objects and their purpose. The play setting offered the children the openness and freedom to be creative. What a wonderful way to begin the journey toward scientific literacy!

Checklist of Literacy Explorations

- Document any new play themes, dialogue, and actions that arise in the science literacy center following the guided science experience.
- Informally question and interview the children about the guided experience and their thoughts about science, scientists, and the science literacy play center. Listen closely for facts, opinions, and attitudes. Ask the children to explain why they feel the way they do; probe for thoughts behind their answers.

The six week adventure of the establishment of a science literacy center in a classroom for young children is a dynamic vibrant opportunity to watch and learn much about a child's perspective of their world. Bringing science into the early childhood setting must be done through an appropriate means. Children tell teachers much about how they learn, what they like, what excites them, and what threatens them, but one must stop to look and listen. One of the best places to see and hear children express themselves and see children experience their world is through their play. Allowing "science" to grow with children as they play is to understand how important it is to value children's world views, histories, and futures. There could be no better environment for children to experience their first notions of formal science than through the open, nurturing, curious, creative, exciting world of play.

About the Authors

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Appendix

Science Literacy Centers

Science Literacy Center: Fix-It Shop

Topic or Theme: Things that Go.

Science Materials and Equipment:

Toys: Cars, airplanes, trucks, bicycles, skateboards, roller blades, boats, Legos, Duplos with tires

Tools: Screwdrivers, wrenches, hammers, nuts, bolts, screws, wires with alligator clips, magnifying lens, workbench

Electronic Equipment (working and non-working): VCR, record player, tape recorder, CD player, microphone, typewriter

Clothing: Work gloves, work apron, rags, work caps, safety glasses, overalls

Traditional Literacy Materials:

Bills, receipts, diagrams of problem, diagrams of parts, letters, logbook

Miscellaneous Literacy Materials:

Money, cash register, telephone

Science Literacy Center: Weather TV News Room

Topic or Theme: Seasons and Weather

Science Materials and Equipment:

Tools: Rain gauge, anonometer, maps, barometer, thermometer, antenna, satellite photos

Clothing: Rain coat, hat and boots, snow shoes, umbrella, winter jacket and mittens, sports jacket and tie, dress, summer swim gear

Traditional Literacy Materials:

Charts, graphs, pictures (clouds, storms, etc.) scripts, logbook, clipboard, typewriter, computer

Miscellaneous Literacy Materials:

Microphone, camera, desk, chair, head phones, cue cards

Science Literacy Center: Hospital Emergency Room

Topic or Theme: All About Me

Science Materials and Equipment:

Tools and Materials: Skeleton bones (chicken, cow), parts of the human body models (eye, ear, skull, brain, etc.), height and weight scale, plastic hoses, cast material, plaster of Paris, jars of cotton balls, blood pressure cuff, stethoscope, tongue depressors, reflex hammer, plastic syringes, thermometer, examination table, crutches, wheel chair

Clothing: Surgical greens (clothing) rubber gloves, paper patient gowns, white lab coats, nurse hat, masks, booties, eye patches, ace bandages

Traditional Literacy Materials:

Prescription pads, anatomy book, X-rays, patient charts, graphs, eye chart, growth chart, CPR chart, clip boards, Mr. Yuk poison stickers,

Miscellaneous Literacy Materials:

Beepers, telephone

Science Literacy Center: Flower Shop

Topic or Theme: Things that Grow

Science Materials and Equipment:

Tools: Watering cans, pots and planters, garden tools, trellis, soil tester, scissors, artificial flowers, dirt and sand, wheel barrow, seeds and small plants, shovel, moss

Clothing: Garden gloves, apron, sun hat, knee pads, sun glasses, tissue and foil paper

Traditional Literacy Materials:

Bills, receipts, order sheets, price tags, pencils, pens, markers, measuring tape and rulers

Miscellaneous Literacy Materials:

Seed packets, delivery boxes and sheets, plant journals, money, cash register, telephone

Chapter 13

Motion at the Activity Center: Children's Experiences With Physical Science

Leslie Irwin & Jophus Anamuah-Mensah

"It's ice coke," shouted Stan, an eight year old boy, to his older brother Ebow as he pointed to a bottle of Coca-Cola in his hand. "How did you make it?" Ebow inquired, and then added "I think it is frozen." " No, let me show you," Stan said as he took another bottle of Coca-Cola from the freezer. "See! It 's not ice; I'll open it," Stan continued. As soon as he opened the bottle, the liquid started turning into "ice" crystals with some exuding from the bottle. "You see, I told you," Stan shouted excitedly again.

Children by nature seem to be on a constant quest for knowledge, they are on a never ending exploratory mission, busily looking, smelling, touching, listening, wondering, and physically doing things in their environments. There is excitement in their quest to understand their surroundings, how things work, how they affect, and in turn are affected by their surroundings. Like scientists, children have a uniquely inquisitive nature, and a curious habit (Pearlman & Pericak-Spector, 1995), they make guesses, observations, measurements, experiments, estimates, discuss with friends, and draw conclusions. This innate propensity to freely explore the physical environment and make sense of it may easily be stifled in the typical classroom where teachers use the chalk and talk approach, perform teacher-centered demonstrations, and lack experience in handling children's questions. This natural urge to be curious can be enhanced and supported in a classroom environment that incorporates activity centers (Nimnicht, McAfee, & Meier, 1968). Working in such responsive environments, as they are sometimes referred to, requires teachers to understand children's perception of science.

For children, science is more a process, than an end result activity, one that is open-ended, self-paced, and whose direction is determined primarily by the children (Althouse, 1988). As a process, science enables children to engage in hands-on, minds-on activities. Physical manipulation of objects is the basis of their involvement. When Stan opened the coke bottle, he discovered something new for himself which he incorporated into his knowledge structure by modifying his prior knowledge. Such physical interaction leads to the development of intelligence, and mental adjustments, enabling the child to construct his own knowledge (Kamii & DeVries, 1993). Thus, by directly interacting with objects and situations in their environment, children actively effect changes and modifications in their previous learning; they become authors of their own learning and therefore are able to build a strong foundation for understanding natural phenomena.

This chapter aims to encourage teachers to stimulate and reinforce the natural inquiry attitudes of children through science activity centers in the elementary classroom. The objective is to provide activities that strengthen the rudimentary scientific processes that children naturally use in their manipulation of the environment. The first section of the chapter deals with the nature and goals of activity centers. It is followed by the science inquiry processes children use when interacting with the external world of objects. These processes include observation, classification, measurement, prediction, inference, communication, use of numbers, use of space/time relationships, and drawing conclusions (Althouse, 1988). These are critical to the development of scientific attitudes and problem solving skills which form the basis for developing interest in, and further pursuit of science. The third section discusses the role of teachers in helping children develop a sense of wonder, and the processes of science at the activity center. The chapter concludes with motion of objects in the environment using illustrative activities that provide children with the opportunity to engage in the scientific processes.

Activity Centers

The natural inquisitiveness, curiosity, and creativity of children are characteristics which can be lost if children are neither provided the opportunity to be autonomous, nor a proper nurturing environment (Kamii & DeVries, 1993), in which to freely investigate by interacting with objects. Current teaching methods, and arrangement in most elementary science classes may create an uninviting atmosphere of disinterest to children. Instead of allowing them to directly manipulate objects as a way to generate their own knowledge, children may be spoon fed ready-made information by teachers eager to impart knowledge.

Activity centers provide a means that allows children to develop and hone in on their investigative skills; it enhances and encourages the utilization of process skills that are imperative in scientific inquiry. Activity centers especially for younger children are not separate rooms set up for science lessons as is found in the high schools. Neither are they places for teacher demonstrations, nor for extensions for didactic discourse with children. These centers are not tables at the back of the classroom with an assemblage of rocks, fossils, or shells (Manning, 1980). Activity centers can be designated areas of the classroom, a table or desk, or carpet for one child or a small group where activities and materials are provided. Activity centers can be described as play-based interactive places in the classroom where children have the opportunity to probe and find their own answers to questions posed by themselves or teachers through an inquiry process. In a sense, these are places where children can learn to wonder, question, and think like trained scientists. They provide a "touch, think, and do" environment for children to explore, manipulate materials, and observe the results of their actions without any inhibitions. Activity centers are excellent environments for reinforcing and encouraging the inquiry attitude of children when they are set free to contemplate and wander about in these areas. They question, manipulate, observe the movement of objects in the environment, predict how objects will behave under various conditions, offer explanations, draw conclusions, and discuss findings with peers. Thus, activity centers can be total learning environments where children can pursue their natural quest for knowledge.

According to Norman and Taddonio (1990), these centers provide an opportunity for children to develop cognitive, socio-emotional, psychomotor, and language skills. They describe the goals for socio-emotional skills as those that encourage children to "become more autonomous, respect feelings and rights of others, become more curious and pursue curiosities; have confidence in own ability to figure things out" (Norman & Taddonio, 1990, p. 2). Piaget refers to this as social knowledge, knowledge that is established by society and learned from other people (Wadsworth, 1984). At the center, these objectives can be achieved by encouraging children in groups, or individually to participate in various activities. As extensions to these activities, children can look up reference sources, talk to parents, peers, and older children.

Cognitive goals encourage children to identify problems and formulate their own ideas. Children discover the relationships between objects and events, similarities and differences, they classify or group, order or seriate—mainly qualitatively (big/little, more/less, cold/hot, heavy/light). They explore spatial relations, mostly concepts of position (in/out, to/from, high/low, near/far), and temporal relations, and are able to sequence events in a chronological order (Norman & Taddonio, 1990). Cognitive goals are realized when children are provided with opportunities to interact directly with objects in an attempt to discover relationships between and among the objects.

Language goals enhance oral interaction between children, thus encouraging student initiated questions, and increasing general verbalization with respect to both word variety and length of responses (Norman & Taddonio, 1990). Inviting children to talk about their activities and share their findings with the teacher or other children may promote the achievement of these goals. Teachers may ask questions that do not dictate, but guide children's thinking.

Children develop psychomotor skills as they interact with, or manipulate objects, an important goal for an activity center. Psychomotor goals can be achieved by encouraging children to handle objects, and to use a variety of ways to report their work. They can use drawings and pictures to represent objects and their relationships with one another. In a kindergarten class for example, children can trace their hands on paper and compare their results with others in the class.

Science Inquiry Processes

The variety of science inquiry processes that children engage in, and their interactions with the physical world to gain physical knowledge (knowledge of objects in external reality), include classification, comparison, communication, inference, prediction, measurement, use of numbers, space/time relations, conclusions, and observation. Through these processes, they discover the physical properties and the meaningful relationships of, and among objects. Observation forms the basis of all these processes; thus all physical properties of objects can be known by observation (Kamii, 1992).

Piaget posited that for a child to know an object, he has to act upon it and transform it. This provides the means for children to engage in the processes of science referred to earlier. Children have a natural tendency to interact with objects they encounter in order to discover these objects. This is exemplified by the authors' observation of Esi, a kindergarten pupil who was handed a tennis ball, she looked at it intently, grabbed it, squeezed it, and finally threw it at the wall. The ball bounced back, she retrieved it, threw it again and again at the wall, discovering that the ball would bounce back to her when she threw it to the wall. Esi observed, experimented, and made inferences in this activity as she "acted" on the tennis ball. Through years of experience with elementary classroom science activities, the authors have made numerous observations of children utilizing the various processes that describe the scientific inquiry. These processes are briefly described below.

Observation

Children are continually observing and noticing stationary and mobile objects in their environment. Their sense of seeing, hearing, feeling, and smelling are sharpened, and since these processes are paramount in focusing children's interest and wonderment, teachers need to provide activities that develop all their senses.

Classification

When exposed to objects with different attributes (e.g. color, size, shape), children tend to group the objects according to what interests them. They invent their own classification systems. A child playing with Lego toy vehicles may separate the small cars from the trucks, or grouped the cars by color. The physical properties of the toys are employed to form relationships among them.

Comparison

Children compare attributes of objects and make distinctions between and among them. Comparison may lead to the arrangement of objects according to size, shape, color, length, diameter, speed, and other characteristics. This process of relating objects to one another is referred to as seriation. An example of seriation is when two children playing with toy cars on an inclined plane decide to find out which car travels the furthest. The cars roll down an inclined plane until they come to a stop. This is repeated for all cars. The children then order the cars, with the one that travels the furthest in the front, followed by the next, until the last.

Communication

In the classroom, children share their information with peers and teachers. The communication process allows them to develop spatial representation, language, and social skills. Children communicate their findings in a variety of ways. They may produce drawings or verbally share their results, as exemplified in the introductory dialog, when Stan excitedly announced his discovery to his older brother. It is the authors' impression that children are ecstatic about, and willing to share, their discoveries with anyone willing to listen.

Inference

Children often guess or make inferences based on their observations, and the prior knowledge they bring to these observations as they interact with their surroundings. Children can be encouraged to make inferences on their interactions through thought provoking questions. How did water droplets appear on the outside of the coke bottle? They can also be encouraged to ask questions.

Drawing Conclusions

Children draw conclusions through observations and interactions with objects. They may continually modify these conclusions as they further engage in these interactions. At an activity center, children were asked to mix green and yellow paints, and to share their observations. One child remarked that he had made different "kinds" of green, implying different shades of green. Asked whether they were the same, the child replied, "No." When asked how he made the light green, he replied that he had used a lot of the yellow and a little blue paint.

Prediction

Prediction involves making guesses about what the result of events will be. Children can be encouraged in a variety of ways including questions, and observations to make predictions. In a science activity involving the boiling of beans, a group of kindergarten children were encouraged to predict whether the boiled beans would be hot to touch, and if the size and color of the beans would change. By predicting, children think ahead and they think about cause and effect relationships—both are necessary to generate accurate predictions.

Measurement

Measurement is the process of figuring out the amount, or extent of something. Children are confronted daily with the opportunity to measure. Measurements may be only approximations, and are done in numerous ways, utilizing all kind of objects such as dowels or sticks of various lengths, strips of paper, fingers, feet, or by drawing pictures.

When grade two students were encouraged to measure the length of the classroom by using any means they could think of, one child used his feet and counted the number of steps (feet). Another laid full length on the floor, marked where his head was, and repeated this until he got to the opposite wall. Other children used threads, rulers, and sticks.

Teachers' Role in the Activity Center Approach

Teachers play a significant role in engaging and enhancing the enthusiasm of discovery in children, and understanding this role and how learning is effected in young children can determine how teachers design and implement activities at a center. Teachers play a meaningful role in facilitating the success of children's experiences with their physical environment by setting up the classroom to invite and motivate the inquiry process. Actual "physical knowledge can be constructed by the child only through acting on objects, and the teacher's role here must be to assist the child in this process rather than to serve as the source of knowledge" (Kamii, & DeVries, 1978, p. 23). Teachers empower children to experiment with the materials that they have made available at the activity center. Teachers' involvement is one of resource persons, assisting students when necessary by asking guiding questions that help students arrive at their own answers and conclusions. Teachers' roles in children's inquiry activities therefore is one of indirect teaching, which "can vary from encouraging the child to put all kinds of things into all kinds of relationships, to asking him to get just enough plates for everybody at his table" (Kamii, 1992, p. 27).

Teachers must realize that children come to school with some prior understanding of objects in their physical surroundings, and the effects of their interactions with these objects. Their first science classroom may well be their home kitchen floor where they explore with pots and pans and other household items. They create sounds from clanging pots and pans, splashing water, and numerous other "experiments" in the kitchen and anywhere else in the house. They determine their own experiments, invent their own problems, and construct relationships, with little interference or directions from others. This approach ought to be complemented during school science activities. Teachers need to utilize this awareness of children's behavior in designing activities. They can set up activity centers with various materials for children to handle and play with freely. A wide variety of materials, not necessarily store bought, but those that abound in the surroundings of children can be provided. These are materials that children can manipulate in any fashion without creating adult concern for destruction, or cost of replacement; materials that children can modify with free imagination. Manipulating or modifying objects to take new shapes or forms pose new questions for further investigation thereby developing children's cognitive abilities. Teachers should endeavor to plan and create centers that allow for hands-on manipulative play-learning types of experiences, "activities that permit young children to *act* on objects and to *observe* the results of their actions on objects" (Althouse, 1988, p. 15). By modeling appropriate attitudes and scientific habits in the classroom, teachers can maintain children's interest in science activities. Careful and logical selection of age and ability appropriate activities are vital in providing this meaningful experience to young children.

According to Brown (1981), children are not really taught science formally, rather they teach themselves when provided with encouraging and enhancing environments and materials. Teachers should realize that children are likely to continue in activities that are exciting and interesting to them and for that reason provide an environment that motivates them to want to know and do things. To rekindle and maintain the natural curiosity and fascination that children have for science, teachers must ensure that the activity center is a dynamic area providing novelty, through constantly adding, renewing, or changing items, themes, and design. Teachers designate and constantly refurbish an easily accessible area of the classroom as the activity center for children to explore, manipulate, and learn science. The degree to which children's interest is rekindled, and the extent of their enthusiastic responses to participate, will be impacted by how items or objects for activities are introduced by teachers. Teachers in science learning activities are "exciters," and resource persons who actively engage children in activities, by invitingly introducing materials in a variety of ways to entice, appeal and attract children's interest, enthusiasm, and curiosity. Children have a natural attraction toward anything and almost everything in their field of vision, and considerably within their reach. A glimpse at materials at the activity center provides an enticement, an invitation for children to interact, and out of a sense of wonder, they become inquisitive and finally gravitated towards these items.

Knowledgeable science teachers seize such "inquisitive" occasions to pose open-ended inquiry type questions to focus children's attention and involvement, thereby heightening their interest in the inquiry processes. The positive interests and demeanors of teachers will encourage or plod children to "dig in" and freely explore, manipulate, and interact with the materials at their disposal. This does not relegate the teachers to a function of passive observers, but as active participants in the children's wonderment and excitement by inquiring after what children are discovering, and how they rationalize certain of their responses to teachers' inquiries. At the activity center, teachers are not demonstrators, but are "seekers" themselves, thus modeling "scientific behavior" to the children and providing cues and new ways of exploring items at the center. Children will talk among themselves, or ask questions of which teachers do not provide answers but redirect these questions into problems for children to investigate. Teachers can initiate activities by asking pertinent questions which according to Gega (1994), will guide children to observable variables and lead to the discovery of conditions that affect objects. These guiding questions which are intended to motivate children to interact with objects are very important especially at the pre-K to grade 1 where children may not be able to read. This is in consonance with teachers' "responsibility to help children focus attention on their actions on objects and the results of their actions" (Althouse, 1988, p. 20).

Brown (1981), enumerated certain guidelines for teachers in his "Ten commandments for teaching science to children," which are as follows:

1. Give every child a chance to be a part of the experiment with special emphasis on the use of the senses.
2. Make everything as non-threatening as possible.
3. Be patient with children.
4. Allow the children to control the time you spend on an experiment.
5. Always use open-ended questions.
6. Give children ample time to answer questions.
7. Don't expect "standard" reactions and "standard" answers from children.
8. Always accept divergent answers.
9. Be sure to encourage observation.
10. Always look for ways to extend the activity (Brown, 1981, p. 14).

Similar suggestions for effective teacher facilitation of children's involvement in science learning have been expressed by Woodard and Davitt (1987). They indicate that by the very nature in which children learn, that is by the exploratory hands on approach, teachers as facilitators initiate and encourage children's involvement in physical science by "creating a stimulating and challenging classroom environment, acting as a catalyst, supporting and extending the explorations as necessary, encouraging the child to explore in *his* own way, focusing on 'what' is happening rather than 'why' it is happening, initiating peer/peer interactions" (Woodard & Davitt, 1987, p. 20). Though teachers do not directly dictate the direction of children's exploration, they are instrumental in effecting learning in a variety of ways as indicated earlier. Gega (1994), maintains that a child's performance or approximation of solutions will elicit those questions that will guide him/her to arrive at some answers. Teachers invite and encourage children to experiment and seek out solutions for themselves, and when necessary, are encouraged to ask questions for which various possible approaches to solutions are hinted, or for which some clarification is provided to guide activities. Children are then "unleashed" to experiment on their own. Samples activities that provide opportunities for children to engage in the processes of science at activity centers are described below.

Illustrative Activities: Setting Objects in Motion

A phenomenon that often attracts the attention of children is the dynamic world of moving objects around them, hence the open invitation to investigate. They are fascinated by the movement of objects in the air; they kick and throw stones and other small objects, discovering and learning about the properties of these objects and their interactions on them, thus providing opportunities to observe the regularity of their actions (Kamii, & DeVries, 1993).

This section of the chapter discusses centers with activities that focus on objects in motion. Sample activities are provided to demonstrate how they can be presented by teachers to encourage the application of the inquiry processes so prevalent in the natural activities of children. Sample activities include (a) moving objects by blowing, (b) moving objects by pushing/pulling, (c) moving objects by projecting, and (d) moving objects by swinging.

Moving Objects by Blowing

Focus

High winds can uproot trees and blow away roofs of houses. Sailors use sails aided by wind to move boats on bodies of water. Windmills are used to pump water for irrigation and other uses. Wind is used to generate energy for electricity. The rush of air from the lungs through the mouth can be used by children to move objects, and in the process learn about the attributes of objects (Althouse, 1988).

Activity 1: Blowing Objects Across a Target Line

Materials

Table, non-flexible jumbo straws, masking tape (for target line), variety of small objects (ping pong ball, cotton ball, yarn ball, bottle cap, crayon, pencil, styrofoam piece, plastic flower and a wooden block and bead), two cardboard boxes with "Yes" and "No" signs.

Procedure

Place the materials on the table and use the masking tape to mark a target line. Allow children to blow the objects one at a time across the line from designated positions. Let children experiment by firstly blowing air directly on the object, repeat the experiment but this time blow air through a straw. Children classify the objects into "Yes" (can blow across line) and "No" (cannot blow) in both experiments.

Processes

The following scientific processes can be encouraged as children interact with objects at the activity center.

Prediction. To get the children to make predictions, allow them to handle the objects, and ask which objects they think can be blown across the line, and why. Let children guess answers before attempting the activities.

Observation. Children observe the effect of air pressure on a variety of objects. Use questions such as: What happened to the ping pong ball when you blew on it with the

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straw? What about the cotton ball? The children can be guided to make inferences. Why do you think the ping pong ball is easier to move than the wooden block? Typical responses from children are likely to include differences in weight, shape, texture, and surface. Lighter objects are easier to move than heavier ones; round objects are easier to move than flat ones; smooth-surfaced objects are easier than rough-surfaced ones. Children can also be encouraged to make inferences based on the effect of blowing with the mouth, and the straw. Why is it easier to move objects across the line with a straw? *Classification and Comparison.* Children classify objects when they place those that can be blown across the line in the "Yes" box and those that can not, in the "No" box. Further classification can be encouraged by asking the children if the things that can be moved across the line seem lighter than the others. As the children do this, they also compare the objects according to other characteristics, such as weight, shape, and size. Comparisons can be made between the effects of blowing with or without the straw. What happens when you blow through the straw? What happens when you blow without the straw? Does it make any difference on the objects you blew on? *Communication.* Encourage children to share their results with their peers by showing, and talking about them. Have children compare the objects in the "Yes" and "No" boxes. They can draw items, and orally communicate their observations to others in the class. Words such as, "hard to move," "round," "effective" and "easy" may be introduced to increase children's vocabulary, and to encourage them to incorporate such words in their sharing.

Conclusion

Children can be encouraged to draw conclusions by asking such questions as, Why does this method move the objects? Why do you think they were easier to move? Comments by children such as, "The ping pong is round, it is like a ball, and the wooden block is heavy," were noted by the authors. Others conclude that light and round objects are easier to move by blowing.

Extension

This activity can be extended by:

1. Encouraging children to choose other objects in the room and try blowing them across the line.
2. Creating a game that will require children to blow only two times on the object, and then classify each as "Yes" or "No." For the very young, the target line can be moved closer to the objects.
3. Blowing through a cardboard tube (from toilet roll) or other items that children can blow through. Encourage children to make comparisons with the use of straw, tube, and just by mouth. Asking guiding questions such as: What happens to the objects when you blow through the tube? Is the result the same as blowing without the straw? Why?
4. Introducing spatial relations and measurement. This can be accomplished when children are encouraged to blow on every side of the object using the straw. What happens when you blow on the sides of the object, underneath, on the top? Allow children to experiment with varying distances between the straw and the object, to discover for themselves what impact if any distance has on moving the objects.
5. Asking children to try moving the objects on a rug. They can be encouraged to predict and compare, by asking them what they think will happen when the cotton

ball is blown on the rug. How does movement of objects on the table compare with movement on the rug? Children can make inferences when asked why they think the objects moved slower on the rug than on the table. For older children the word "friction" can be introduced and explained so they can incorporate it into their vocabulary for future use.

Moving Objects by Pushing/Pulling

Focus

At the center, children play games and perform activities that involve exerting force on objects to slide or roll. Pushing and pulling occur when force is applied to an object. This involves moving an object over a stationary object or surface. The force applied to the object is counteracted by an opposing force or friction which acts on the surface over which the object moves. When the applied force is larger than the friction force, the object moves. Heavier objects tend to require greater force to push or pull than lighter ones. This is a result of the greater amount of force pressing the surface of the object to the surface on which the object stands. A greater force is required to move an object on a rough surface than it is for a smooth one. If both the object to be moved and stationary surfaces are rough, a greater force will be needed to push or pull the object. A rough object pulled or pushed over a rough surface will require a greater force than a smooth object moving over the same surface.

Activity 2: Pulling Down a Container

Materials

A small container (basket), elastic band (tied together at one end to make a loop, and tied to a basket at the other), cord (pass through elastic loop and tie to door knob), pebbles, cotton balls, chart (with numbered colored lines), popsickle stick (attached to the basket to serve as a pointer), magic markers (to color pointer lines on chart).

Procedure

Tape the chart on the lower part of the door under the knob (see Figure 13.1). Attach the basket to the elastic band and cord on the door knob so that the basket hangs. Allow children to press on it to experience the lowering effect of the elastic. Children then add the pebbles and the cotton balls one at a time to lower the basket. They observe how far down the basket's pointer goes on the chart. Children select a line either by color or number on the chart, and use the pebbles to lower the basket's pointer to that line.

Observation. Encourage children to observe the movement of the basket as the different objects are placed in it, and ask such questions as, What happens when you put pebbles in the basket? What happens when only one pebble is placed in the basket? What about one cotton ball? What happens when you take all the pebbles and cotton balls out of the basket? What happens when

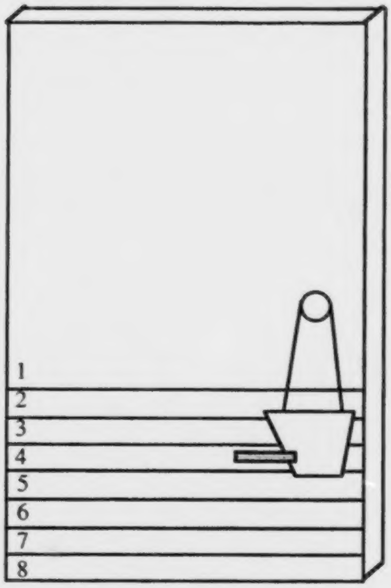

Figure 13.1 *Pulling down a container.*

you put all the pebbles in the basket? What about all the cotton balls? Typical responses from children may be, "The basket goes down." "The pointer moves." "It (the pointer) points to the red line."

Inference and Comparison. Children can be encouraged to explain their observations by asking questions such as, Why did the basket move down when you added the pebbles? Why did it move very little when you put the cotton balls in it? Children can compare the extent to which the basket is lowered by objects of different weights. Did the cotton balls lower the basket to the same level as the pebbles? Why? Children may answer, "The pebbles are heavy and they lower the basket," "The cotton balls are light so the basket did not go down." They make an association between the weight (force) exerted by an object, and the distance to which the elastic is stretched.

Prediction. Before children engage in the activities, allow them to predict what will happen when an object is placed in the basket. Subsequently, they can be asked what they think will happen if the basket is completely filled with either pebbles or cotton balls. Engage children in follow up probing questions to ascertain their prior knowledge of the phenomena in the activities.

Measurement and use of Numbers. Children use the lines on the chart to measure distances to which the basket is lowered when objects are placed in it. They can identify and use numbers in phrases like "two lines down, 5 lines down, line number 2, or line number 5," to describe the distance between a designated point and a new level of the pointer. Encourage children to use numbers by counting. How many pebbles are needed to lower the basket to the nth line (designated number)? From the nth line, how many pebbles did you add to get to the next line? How many pebbles are needed to lower the basket to the floor? This enables the children to count, add, and subtract.

Conclusion

Guide children to draw, and orally communicate conclusions. They may discover that heavier objects tend to stretch the elastic more and therefore lower the basket more than lighter objects. Children may also conclude that a large number of lighter objects can lower the basket to the same level as a few heavier ones.

Extensions

1. Numbers can be substituted with colored lines for children to identify as the pointer indicates. How many pebbles will it take for the pointer to get to the blue line? With the very young, this will enhance the recognition of numbers and colors.
2. Children can use other available objects in the classroom, such as little wooden or plastic blocks and pieces of paper in place of pebbles and cotton balls.
3. Older children can discover other ways to measure the length to which the basket is lowered. They can construct their own charts to document their observations.

Moving Object by Projecting

Focus

Children may frequently engage in throwing, and/or catching objects such as a ball, a pebble, or any playful object during play activities. Sometimes a target is aimed at, but in most cases it is just nonpurposeful throwing. The object thrown is referred to as a projectile. A projectile's movement is affected by a number of forces, namely the force of gravity which pulls it to the earth as it moves in the air, the force of the throw which gives it the initial tendency to move, and the force of air resistance which tends to slow it down as it moves. Objects such as a ball, tend to travel longer distances when thrown at elevated angles than when thrown in a horizontal direction. Consequently, a horizontally thrown object will require a greater throwing force to cover the same distance as one thrown at an angle.

Activity 3: Tu-matu (Hopscotch)

Materials

Chalk (to draw the hopscotch, a pattern of eight rectangles), a small bean bag, an empty milk carton (cut and folded into a cube), dice (made from milk carton cube, with numbers 1 through 6 each written on a side), a chart (with names of participants, and spaces for recording scores). See Figure 13.2.

Procedure

One child at a time throws a dice to determine which corresponding number (rectangle) on the Tu-matu to throw the bean bag. Standing at the starting point, the child throws the bean bag into the rectangle with the corresponding number indicated by the dice. If she or he succeeds, the appropriate number is recorded on the chart below his or her name. Each player continues until she or he fails to land a bean bag on the designated space of the Tu-matu. The next player then takes a turn. This continues until a player covers all the numbered rectangles. The scores are tallied, and the winner is the one with the greater score.

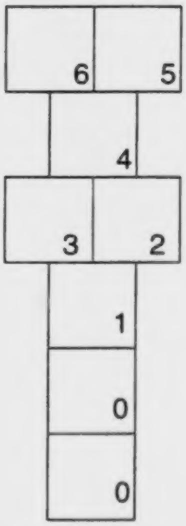

Figure 13.2 *Hopscotch*

Processes

Observation and Communication. Encourage children to observe the movement of the bean bag as it is thrown. They discover how much force to apply (in the throw) to the bean bag to reach its target. Encourage children to communicate their activities and observations both verbally, and through drawings. How did the projectile move? Did you have to throw the bag a little harder to rectangle 6? Draw the path of the bean bag when it is thrown.

Comparison and Inference. Asking children questions can guide them to make comparisons and inferences. Is it easier to get the bean bag onto rectangle 4, 5, or n than rectangle 1, 2, or n? Why?

Spatial relations. In this activity, with the throw of the dice, children discover spatial relations as they relate the number on the dice to the corresponding one on the rectangle. How does the result on the dice relate to the numbers on the rectangles?

Use of numbers. Recording scores allows children to practice writing, as well as adding numbers. They can be encouraged to record their scores in whatever way they choose. What was your total score? If the children have only learned how to add two numbers, restrict the addition to two numbers at a time.

Conclusion

Guide children to draw conclusions from the activity. They may say, "You have to throw the bean bag with more force if you want to put it in number n" (designated number).

Extension

1. Children who can not add numbers, and, therefore, are unable to tally scores need not do so. They can call out the numbers and move to the corresponding spot on the Tu-matu. They can identify numbers this way as they observe and compare.
2. Boxes can be placed in the rectangles to act as targets into which the bean bag is thrown. Children can find in the classroom their own small items to use as projectiles. This throwing activity can improve psychomotor skills.

Moving Objects by Swinging

Focus

Swinging involves moving a suspended object back and forth. A simple swing can be made by suspending a weight or bob on a string attached to a support. This swing is called a simple pendulum. The time that it takes to swing the pendulum once (also referred to as a period) is independent of the weight of the bob. Irrespective of the weight, a light bob will have the same rate of swing as a heavy one. The length of the pendulum however will affect its swing. The longer the pendulum, the longer will be the arc of the swing (or the amplitude) and the slower its period or swing. A shorter pendulum will make a shorter arc and produce a faster swing. The longer arc made by the longer pendulum covers more distance than the shorter arc.

Activity 4: Swinging Sand

Materials

A cardboard box, a paper cup (with a hole in the center of the bottom), string (tie to sides of cup, hang from box about one inch above bottom of box), sand, a scoop, colored paper (to fit bottom of cardboard box), glue.

Procedure

Children push the pendulum (the string and cup) gently to observe its movement. They place a colored paper on the bottom of the box, then put some sand in the cup and gently push the pendulum. As the pendulum swings, the sand pours out through the hole in the bottom of the cup, making a design on the colored paper. Children repeat the activity, using various lengths of the pendulum, and various amounts of sand in the cup.

Processes

Observation and Comparison. Children observe and discover the direction of movement, and the design of the sand on the colored paper as the pendulum swings. Encourage them to compare the designs made by various lengths of the pendulum, and observe the swing with different amounts of sand. How is the design made by the longer pendulum different from that of the shorter pendulum? Is there a difference between patterns made by the half-filled and full cups of sand? What is the difference? Children may develop ideas about the effect of the "heaviness" (weight) on the swing.

Space/time relations and Use of Numbers. Children discover that swinging the pendulum in the same direction creates similar designs within the same area on the colored paper. Children observe the boundary of the design. Encourage older children to use time relations. Using a timer, encourage children to count the number of times the swing comes towards them in five, ten, and fifteen second intervals. How many times did the swing come towards you in five seconds? This encourages counting.

Prediction. Encourage children to predict, by asking such questions as, How can you create a circular design with the pendulum? How can you make the pendulum move to the left corner of the paper?

Measurement. Measurement can be introduced into the activity by encouraging children to use paper strips or anything they can think of to measure the length of the designs made by the long and short pendulum. They can also measure the length of the designs made by the half-filled, and full cups of sand.

Communication. Encourage children to share orally, and by drawings, the various designs. Introduce and explain new appropriate terms such as "pendulum," "faster," "slower," and "swing," and encourage children to incorporate and use them for a more effective communication of ideas. This will enrich their vocabulary.

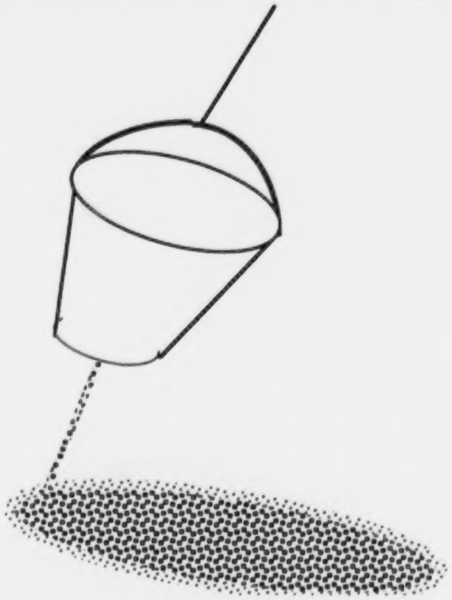

Figure 13.3 *Pendulum*

Inference. Ask children guiding questions on their observations and encourage them to make inferences. Why are the designs made by the shorter pendulum different from those of the longer pendulum?

Conclusion

Through the manipulation of the pendulum, children may conclude that the longer the pendulum, the longer the design. Older children may indicate that the amount of sand in the cup does not affect the number of swings.

Extension:

1. Children can make permanent sand designs by applying a light coat of glue on the colored paper before letting the sand run on it. The sand sticks to the glue when it dries, creating a permanent design.
2. Younger children can just play at swinging various lengths of the pendulum and observing, without having to time the swing.

Conclusion

The emphasis of this chapter has been on process skills acquired through manipulation of objects in the environment to gain physical knowledge. It is suggested that teachers of science to younger children engage in the habit of letting children take control of their science learning. This does not take away from teachers' responsibilities, but enhances the discovery attitudes of children. Science learning for children is a constant "on the job training," an ongoing process that they create for themselves to understand their environments. Children display the processes of science in their exploratory activities, physically manipulating objects and ultimately resolving uncertainties and satisfying curiosities. The activities further reinforce fundamental process skills that children naturally employ in their manipulation of the environment.

In the classroom, these activities can take place at science centers set up by teachers to provide the kinds of opportunities that benefit children and complement their interests in physical science. The illustrative activities in this chapter exemplify how easily and unsophisticated it is to involve children at science activity centers. They provide a means to engage in the scientific processes described in the chapter.

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Chapter 14

The Mysteries of Matter

Jodi DeSantis

The components which make any given primary classroom science lesson successful are as follows: (a) the assessment of children's understanding of a particular concept, (b) opportunities to explore and experiment in order to test their understanding, (c) questions from the teacher or classmates which may guide that exploration, and (d) a discussion which enables children to modify their original hypotheses in accordance with what they have discovered.

The establishment of learning centers enables the teacher to address each of these four components in a most effective manner. Each center described below is designed to allow for experimentation and exploration. Materials are provided for children to test their hypotheses. Since it is not possible to predict with complete accuracy what those hypotheses may be, materials in addition to the ones noted here may be needed.

At each center, children will answer a number of questions before, during and after engaging in a given task. These questions will not only enable the teacher to ascertain children's preconceptions about the idea being investigated, but even more importantly will provide guidance for children as they conduct their investigations. To be exact, rather than including step-by-step instructions, each center is accompanied by a list of "Questions for Exploration." Such questions could be asked at any point during a given activity depending upon where the teacher feels they would be most appropriate or effective. For example, they may be used as a basis for children's predictions, as a method of directing children to the next step of a given investigation, or as a reinforcement of what the children have learned. In some cases, children may be asked to return to the original answers they gave to certain questions in an effort to incorporate the new knowledge they gained from engaging in a number of activities at a particular learning center.

The learning centers described below are geared toward use with grades kindergarten through three and are connected by a common theme, that is, "Solving the Mysteries of Matter." Investigations include various ways to measure solids and liquids as well as measuring changes in the states of matter. Mathematical concepts such as measurement, addition, subtraction, and graphing are reinforced through the various activities in which children participate.

Perhaps most importantly, children seek to reevaluate their definitions of solids and liquids as they determine the distinguishing features of each. They will accomplish this goal by thoroughly examining the observable properties of solids versus liquids as well as by exploring ways in which to create conditions that will change those observable properties. Ultimately, they will test their new found definitions of a solid and a liquid by categorizing unknown materials as one or the other.

Six centers will be established and each one will serve to assist children in answering a particular question by providing them with a number of opportunities for investigation. Each child should be assigned a partner with which to visit each center so that they will have the opportunity to question, argue, and share with one another.

Centers One through Three engage children in examining the observable properties of solids versus liquids. Center Four allows them to observe how solids and liquids interact with one another. Center Five gives them a chance to investigate ways in which they can change the observable properties of solids and liquids. Center Six provides children with a culminating activity which enables them to test their new found beliefs about solids and liquids, as they seek to categorize various materials as either a solid or a liquid.

Prior to having children engage in the activities presented at the centers, the teacher should assess children's understanding of a solid and a liquid as well as the differences that exist between the two. Children may find support for their beliefs by extracting evidence from their personal experiences with various solids and liquids. It is this assessment which will enable the teacher to provide children with the most enriching learning experiences possible.

Center 1: What is a Solid?

At this center, children will seek to define the unique properties of a solid as it is distinguished from a liquid. They will explore a number of different solid materials and describe the properties of each.

Identification of Properties Activity

A rock will be presented to the children as an exemplary solid. Children will be asked to brainstorm words that describe the rock. They will then examine the following set of solid objects: a plastic triangle, a cloth square, a plastic tube, a wood cylinder, a popsicle stick, a screw, and a wire with plastic insulation. Children will use their own vocabulary to describe each of these solids and then may be provided with the following adjectives: flexible/bendable, rigid, smooth, rough, soft, hard, colored, pointed, flat, transparent, opaque.

Questions for Exploration:

- How could you describe each of these objects?
- What do they look like (i.e., size, shape)?
- What do they feel like (i.e., texture)?
- Are they heavy or light?
- What do they sound like?
- What can we use to measure these solid objects?
- What is the length and width, in centimeters, of each?

Classification Activity

Children will find ways to classify these objects into groups according to their common properties. Children will count the number of solid objects in each group. They will then rank the groups from the one which contains the most number of objects to the one which contains the least number of objects. Finally, children will create a bar graph displaying this information. The x-axis will show each group's "title" and the y-axis will show the number of objects in each group. In this way, children will begin to notice which properties are most common among solid objects.

Questions for Exploration:

- What is the same about these solids?
- In what ways could we put them into groups?
- In what other ways could we put them into groups?

Construction Activity

In order to become more familiar with these solids, children will construct a tower (and other structures) using the properties inherent in the materials to accomplish the task. They will be provided with the following: one straw, one piece of aluminum foil, one rubber band, one piece of cardboard, one paper cup, one popsicle stick. Children will understand that a tower is a tall structure which stands up by itself, as they attempt to create a tower in the most practical manner using the above materials.

Questions for Exploration:

- What do you think is the best way to make a tower using these materials?
- Why is this the best way?

After completing the Identification of Properties Activity, the Classification Activity, and the Construction Activity, children will consider the following:

- What was the same about all the solids with which you worked?
- What was different about them?
- What do you think is the meaning of the word "solid"?
- What do you want to do to find out more about solids

Investigation of Particulate Solids Activity

This activity is an interesting one in that children's existing definitions of a "solid" will be challenged. For example, the small solid materials used in this activity (as opposed to the solid materials used in the previous activities) can be poured. For this task, children will work with lima beans.

Questions for Exploration:

- How can we measure these solids?
- How are the solids in this activity different from the ones you had used in the other activities?
- How are they the same?
- Look at the meaning you wrote for the word "solid." Do the solids you used for this last activity fit that meaning? If not, how can you change the meaning so that it will apply to all the solids you used at this center?

Center 2: What is a Liquid?

At this center, children will seek to define the unique properties of a liquid as it is distinguished from a solid. They will work with water, corn syrup, liquid hand soap, cooking oil, liquid detergent, and fabric softener as they describe the properties of each.

Observation of Behavior of Liquids Activity

Children will use a sample of each liquid which has been put into a bottle. Children will consider these "Questions for Exploration":

- Are all of these liquids the same? How are they different?
- Do all of the liquids move in the same way?
- What can we use to measure these liquid amounts?
- What happens to the liquids when you slowly tip the bottles on their sides? What happens when you turn them upside down?
- What happens to the liquids when you roll the bottles?
- What happens to the liquids when you shake the bottles?
- Can you make a "tornado" in the bottles? Which ones?

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Children may be introduced to the following vocabulary in order to assist them in defining the properties of various liquids: bubbly, viscous, foamy, translucent, colored, transparent. An example of each should be shown to children.

After this preliminary observation activity has been completed, children will attempt to define a liquid and identify those properties which distinguish it from a solid. In particular, they will consider the ways in which a liquid behaves differently than a solid.

Classification of Liquids Activity

Children will put these liquids into groups according to certain properties. The following can be used as "Questions for Exploration":

- How would you classify these liquids according to how they look?
- How would you classify them according to how they pour?
- How would you classify them according to how they behave when you shake them in bottles?
- How else could you classify them?

Conservation of Liquids Activity

Children will discover what the same amount of liquid looks like when placed in a variety of containers of different sizes and shapes. From this activity, children will learn that a liquid takes on the shape of the container in which it is placed. Children may be asked, "How will this liquid look when placed in Container A? when placed in Container B?", etc. Children may be interested in measuring the amount of liquid in each container to confirm that all containers are holding the same amount.

Absorption of Liquids Activity

Children will experiment with various materials (i.e., paper towel, waxed paper, aluminum foil, etc.) in order to determine which absorb liquids most effectively. In this case, water can be used as the liquid to be tested.

Questions for Exploration:

- Which materials absorb the water best? Why do you think this is the case?
- How do you think the result of our experiment may be different if we use a liquid other than water? Which liquid would you like to use?

Layering Liquids Activity

Children will predict what will happen when they pour one liquid into a cup and then another. They can test two liquids at a time in order to discover which is more dense. They can then begin to combine more than two liquids in order to test their hypotheses about which liquids are more dense and which are less dense. Some suggested liquids to use are honey, rubbing alcohol, syrup, water, oil, and dishwashing liquid.

Questions for Exploration:

- What will happen when you pour one liquid into a cup and then the other liquid?
- What will happen if you reverse the order?

After the above activities have been completed, children should be more familiar with the unique properties of a liquid. Therefore, children will seek to modify their definitions of a liquid as it is distinguished from a solid.

Questions for Exploration:

- How would you define a liquid?
- What do you want to do to find out more about liquids?

Center 3: Differences Between a Solid and a Liquid

Children will observe the behavior of various solids and liquids when water is added to them. This investigation will help children gain a clearer understanding of the difference between a solid and a liquid. They will add water to any or all of the following solids: popsicle stick, rice, cookies, chalk, candy, cardboard, aluminum foil, rock salt, blue cloth, pinto beans, raisins. They will then add water to any or all of the following liquids: liquid hand soap, liquid fabric softener, corn syrup, cooking oil, liquid detergent.

Questions for Exploration:

- What happens to solid materials when water is added to them?
- Will the solid materials return to their original state?
- What happens to liquid materials in bottles when water is added to those bottles? What happens when you leave the bottle standing? What happens when you tip the bottle? What happens when you shake the bottle?

Center 4: How do Solids and Liquids Interact with One Another?

Children will observe what happens when a "mystery solid" (gelatin powder) and a "mystery liquid" (hot fruit juice) are mixed and how the result changes over time.

Questions for Exploration:

- What do you think will happen when you add the solid to the liquid?
- (After mixing the two) Did the liquid change in any way? In what way? Did the solid change? In what way? Where do you think the solid has gone?
- What do you think will happen if we keep the mixture here overnight? (Note: One way to find out if the solid is still in the liquid is to see if the liquid changes. If the liquid changes over time, this may imply that the solid is still there, causing the liquid to change.)
- What do you think will happen if we put this mixture in the refrigerator?
- (After refrigeration) What do you notice?
- What evidence do you have that the solid is still somewhere in the liquid?
- What do you think the "mystery solid" is?
- What do you think the "mystery liquid" is?
- What might happen if we now use a lot of gelatin powder and only a little bit of hot fruit juice?
- What other solids and liquids could we mix together?

Center 5: How Can We Observe Changes in the State of Matter?

Children will work in cooperative problem-solving teams to be the first to melt an ice cube. They will do this by attempting to create the conditions under which an ice cube will melt the fastest.

Rules:

1. The ice cubes cannot be broken, eaten, or placed in anyone's mouth.
2. Each ice cube must remain in its container.

Questions for Exploration:

- What is an ice cube made of?
- Why is it solid right now? How much space does it occupy? (Children can measure the volume of the ice cube by measuring its length, width and height.)
- If left at room temperature, how long do you think it would take for this ice cube to change from a solid to a liquid (melt)?
- What might cause this ice cube to change from a solid to a liquid (melt) more quickly?
- What kinds of things could produce heat to melt this ice cube?
- (If outdoors) Which materials on the playground are warmer than others? Can you find a warm surface on which to set the container that the ice cube is in?
- How might you use body heat to help melt the ice cube without removing the container?
- What could we do to prevent the ice cube from melting?

Measurement

Measurement can be an integral part of this center's activities. For example, children can measure the volume of the ice cube by measuring its length, width, and height. They can also measure the amount of water in milliliters which is present due to the melting of the ice. At this center, they also keep track of the amount of time it takes for each ice cube to melt. They compare these times using the operation of subtraction to find out which ice cubes melted in the shortest and longest amounts of time. Children can then create a graph displaying this information in a sequential order.

Center 6: Is it Solid or is it a Liquid?

At this point, children are given a great deal of autonomy to design their own experiments in an effort to determine whether any given material is a solid or a liquid. Materials such as toothpaste which may exhibit characteristics of both solids and liquids should be chosen to investigate. In this way, children's definitions of a solid and of a liquid will be challenged. An interesting material known as "Oobleck," which can be made by combining corn starch and water, can also be tested. Some questions which may guide children's investigations are:

- How do you really know if something is a solid or a liquid?
- What experiments could we perform on these materials to find out if they are solid or liquid?

If children are having difficulty answering the above questions...

- What do you observe about the material? What does it look like/feel like/smell like/sound like?
- Can you pass your finger through the material?
- What happens when you try to pour it?
- What happens if you drop it on the floor?
- What happens when you put it in a different container?

- What could you do to change one of the properties of the
- What will happen if you heat the material?
- Then what will happen if you let it cool?

Background Information

The information about solids and liquids in Figure 14.1 is presented to assist teachers in implementing the centers.

SOLIDS	LIQUIDS
• Do not change shape easily.	• Change shape easily (take the shape of the container).
• Will not allow another solid to pass through them easily.	• Will allow a solid to pass through them easily.
• Are usually visible.	• May be visible or invisible.
• Have a definite shape.	
• Have a definite size.	• Have a definite size (volume).
• When heated become liquid.	• When heated become a gas.
• When cooled remain in or return to a solid state.	• When cooled become a solid.

Figure 14.1 *Properties of solids and liquids*

Conclusion

Although it is the teacher's hope that children will discover the above concepts as they engage in the various tasks being presented to them, it is most important to note that the experiences that children will have will be meaningful to them, as they begin to develop their own beliefs about various scientific phenomena. Rather than having the teacher define "solid" and "liquid" for them, children will arrive at a "working definition" of a "solid" and of a "liquid" independently, that is, through the myriad of investigations they will conduct. This will enable children as young scientists to internalize the criteria for evaluating whether any given material is solid or liquid. Even more importantly, it will encourage them to explore and discover on their own, to understand how to go about satisfying their own curiosity, and to ask questions that will open the doors to the fascinating world which awaits them.

About the Author

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Section 4

Projects

Section Four offers various examples of projects, representing various age ranges, capabilities, and backgrounds within North America and internationally. All the projects focus on a common project trademark: *investigations that are based on students' experiences and daily lives.* These projects provide students with multiple opportunities to use scientific and mathematical concepts with other content-area knowledge.

Section Four projects also offer students much-needed depth in their learning. The described projects last more than one week, with some projects extending over many weeks or months, adding depth to the learning process. A focus on depth allows students to make meaningful connections to the information gleaned from their inquiry (Allison, in press), and connection-making enables students to "gain insight about people, places, events, and things" (Hartman, 1995, p. 1). Projects, like the ones presented in this Section respect the insight students gain from their extended work.

As you read Section Four, envision the *environments* in which the projects occur. Notice that these environments possess human and physical characteristics necessary for project work (Jones & Nimmo, 1994; McLean, 1995). Keep in mind that you can combine various ideas presented here. We encourage you to tailor projects to your circumstances and use the authors' recommendations to capitalize on students' curiosity to learn.

This Section begins with an introduction to the Project Approach by Jeanette Allison who explains basic implementation processes to consider when including project work in the classroom. The information presented is based on Allison's teaching experience and research.

Following the introduction, chapters focus on projects that have been implemented in classrooms. The first project about *spiders* was developed in a pre-kindergarten classroom in Australia (Ann Smith & Angela Barr). It began with a teacher's real fear of spiders. From there, both she and her pre-kindergarten students faced the fear and learned much in the process. This chapter is very helpful in describing the phases of project development.

Next, Carolyn Eckerty and Jeanette Allison describe a project that Carolyn conducted on *shoes* in her kindergarten classroom in rural Illinois. Many teachers may relate to Eckerty's testimony about her origins as a "traditionalist—even a skeptic" of student-focused learning approaches. The dialogue with students, and details about Eckerty's decision-making processes, are illuminating.

Michael Brody, Janis Bullock, and Julie Bullard follow with their 2nd-grade project on *puddles and ponds.* They provide vivid examples of science and math experiences that help students construct their knowledge about the world, specifically puddles and ponds. They provide an explanation as to why projects assist students so well in their intellectual and social development. This project is a wonderful example of how teachers can integrate projects with activity series and centers.

Finally, Jan Granse provides a wonderful step-by-step account of how her 3rd graders created a *Hot Dog House* project. The "voice" in this chapter is engaging, as she tells about events and decisions occurring throughout the project. This chapter gives an excellent example of how teachers, who work with older students, can find projects very useful for making content, such as math, applicable.

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Chapter 15

The Project Approach

Jeanette Allison

It is the beginning of the school year. Students in a Title 1 preschool program have been watching the older students walk to and from the place "where the big kids eat." Noticing their curiosity, the teacher asks the students during group discussion, "Would you like to find out about the place where the older students eat?" "Yes!" exclaimed the students. Children's interest serves as a catalyst to begin a project. To start their inquiry, the teacher writes a focus question on a large piece of paper: "What Happens in the Cafeteria?"

As students create questions and investigate the cafeteria, the teacher and students expand beyond the focus question to create a semantic map and a chart to help students organize concepts according to what they already know (that the big kids eat in the cafeteria), what they want to learn, and what they learn in the process. For the next four weeks, students engage in simple research to learn *how* the cafeteria operates—who is involved in it, what is in it, when is it used, where it is located in the school, why a school has a cafeteria, and so on. By the project's conclusion, the students will have created many artifacts on their own and with others (e.g., a cardboard "freezer" that resembles the real one). Students then use the freezer and other artifacts for role play (e.g., food warmer made from a large box with square plastic tubs on top). Adjacent to the project, other students use various centers that complement the project (e.g., making menus).

Introduction

This chapter serves as a basic introduction to the Project Approach. The chapter covers:

- A definition of the Project Approach.
- Characteristics of projects.
- A rationale for project work.
- A historical and contemporary look at project work.
- Unique features of projects, compared to unit teaching.
- Implementation of projects.
- Adult and student roles.
- Topic selection.
- Resource location.
- Assessment of projects' effectiveness.
- An overview of Section Four chapters about projects.

What is The Project Approach?

The Project Approach involves in-depth investigations of topics that especially interest students (Hartman & Eckerty, 1995; Katz & Chard, 1989). Students create projects that involve inquiry or research related to children's lives. There is an emergent quality to project work. The project approach is identical to what Jones and Nimmo (1994) call *emergent curriculum*. Emergent curriculum evolves over time, and never really ends. This evolutionary, or emergent, nature of project work adds depth to the learning process.

To ensure depth and emerging ideas, project topics directly relate to people, surroundings, events, and objects that students encounter (e.g., investigating a nearby ravine, a local dentist office, a parade, shoes). Topics further students along in their efforts to construct understanding of the world. The project approach often is identified as constructivist learning. It is a fact; projects require students to be the constructors of their knowledge about their lives. And this construction process is quite social.

What Do Projects Look Like?

There are special characteristics of the project approach that distinguish them from other teaching approaches, such as thematic unit teaching. Projects have many uses; therefore each project has its own "look." There are, however, common characteristics across projects.

Most projects are noticeable by the *constructions* that children create as they move through their investigations. Children use *research*, or guided inquiry, to conduct their investigations and to develop the constructions. The research process includes posing questions; establishing data collection responsibilities; examining various data sources; constructing meaning from the data; and representing this meaning in artifacts such as constructions of environments and objects, murals, artwork, journaling, and role playing (see this chapter's section on "Children's Roles".)

Children's constructions become artifacts that demonstrate their knowledge base. The most common artifacts are structures made from various boxes and odds and ends. Other artifacts associated with projects include murals, drawings, books, costumes, props, and supplementary items such as menus for a restaurant project.

Projects range from small to large in scale, as do the products that result from project work. Small-scale projects such as creating animals from milk cartons and odds-and-ends are developed on table tops. Large-scale projects result in larger artifacts, such as building a house from appliance boxes. Large-scale projects are more popular among children because they can use them in many different ways.

Events and people with whom children come into contact (e.g., field trips, guest speakers) also influence children s work. In one way or another children's constructions will resemble what was seen during a field trip. They also may write letters to a guest speaker or develop follow-up questions to extend the conversations with classroom guests.

Rationale for Project Work

There are many sound reasons why project work is important for young learners. The most salient reason comes from a continued call by researchers and educators to teach for understanding. This call is based on years of research and practice that show how children learn best—in the short and long run (Brandt, 1993).

The call to teach for understanding also stems from research by developmental psychologists who examined the past decade of research on learning. Their research shows that traditional approaches to learning have not been all that effective in helping children learn how to *think* and use their skills in real situations (Gardner, 1991; Hartman, 1993). Furthermore, children are not developing dispositions to be lifelong learners. Instead, they have become conditioned by "the correct answer compromise which promotes routine and narrow thinking" (Brandt, 1993, p. 4; Katz & Chard, 1989).

Thus, calls to teach for thoughtfulness and understanding have come from many directions. Taken together, researchers and educators recommend that schools prepare children to use complex thinking within and beyond the school's walls (Drucker, 1994; Fowler, 1994; Hartman & Allison, 1996). To do so means that children, not objectives, tests, or adults' agendas need to be the focus of education.

Project Work of the Past

A project approach to teaching is not new; the approach can be traced back for decades. Its early proponents included philosophers and educators. Remnants of project work are associated with the "Socratic Method," named after the philosopher, Socrates. He argued that the human mind "acquires" understanding best through interactions with environments and people, rather than simply through observation alone.

In the 17th century, The Committee of Eighteen, consisting of early educators, argued for more "natural" learning. The committee's issues are comparable to contemporary issues involving developmentally appropriate and inappropriate practices. Project-type work was considered to be "appropriate" even then (Snyder, 1972).

Projects were also prevalent during the first half of this century. The Progressive Education Era, for example, is associated most frequently with project work. Examples of projects are evident in descriptions of Dewey's (1916) reconstructions, and Kilpatrick's (1918) project method.

Throughout the years, science and mathematics curricula have been included projects as well. For example, Bruner (1961) argued for project work in discovery learning. Similarly, Thelen (1960) promoted projects within group investigations and problem-solving. Both discovery learning and group investigative learning involve scientific inquiry that is data driven. Bruner (1961) references to the Socratic Method when he explains that we need to acquire data actively, rather than passively.

Project Work Today

Currently, projects are promoted by researchers, educators, and professional associations. Project work can be found in programs that range from developmental to traditional in approach. Some programs offer projects as a regular choice. Children approach projects from many perspectives, using all the content areas along the way. In other programs, projects are attached to a specific content area such as reading. In these cases, children make connections across multiple texts in order to construct meaning associated with literacy. Projects even are advised for working with limited-English-proficient children, and children with disabilities (Hartman & Eckerty, 1995).

Regardless of the era of project work, common elements across projects focus on concepts, real-life contexts, generative topics, scientific inquiry, usefulness of learning, and a democratic learning process.

The Conceptual Nature of Project Work

Project work encourages children to focus on *concepts* in their learning. Concepts are the ideas, messages, and themes behind what children learn. For example, instead of focusing on the word "pets," children go one step further to look for the meaning behind this topic. They study concepts such as, "People Take Care of Pets." Often, it is helpful to focus a topic by posing a question, "What Do Pets Need to Survive?"

With the house project introduced earlier, children may examine concepts such as, "Buildings have windows and doors." As they begin to focus on other details of these concepts, they may discover associated concepts such as, "Buildings need electricity to have lighting," and "Houses have floor and wall coverings." These related concepts would lead children to investigate electricity, lighting, the local electric company, and floor and window coverings. Conceptually-driven project work adds much substance to children's knowledge base. Ultimately, concepts and data drive projects, not pre-established curriculum goals.

The Shifting Nature of Project Work

Even though projects share similar characteristics, each project has its own special focus depending on the topics and children's interests (see Smith & Nassingar-Barr in this section). Therefore, projects have much potential for inquiry that grows from one project to another. Because of the evolutionary nature of projects, teachers often characterize them as *shifting* over time. Usually, the shifts are connected in some way due to the concepts that continue across projects (see Granse, in this section). A project on a construction site, for example, may shift to a related project on houses. A house project, then, might shift to include a post office project as part of an overall larger project about the community. These shifts stem from children's discoveries of new concepts and wonderments that arise during research.

Over time, children build on their original concepts, resulting in better understandings of the ideas, messages, and purposes related to their investigations. Concepts can be recorded as webs, lists, and questions on large paper or in journals (see Eckerty & Allison, Section Four). Teachers need to be "in tune" with these shifts, and view them as opportunities to learn and document their learning. It is important, though,that the shifts maintain some original concepts across time. For instance, the original concept above is that a building (a construction site) provides shelter and a place to work. Across shifting topics (e.g., house, post office), the teacher helps children remember that their constructions are all places of shelter and work.

Implementing Projects

Each project has its own appeal. The details of children's work vary depending on what they know, what they want to know, and what is available to them. And yet, its basic life is similar to other projects, and the learning opportunities that transpire. When implementing projects, it is useful to consider project phases, human and physical environments, topic selection, resources, and assessment. Let us first consider the phases of project work.

Most project specialists agree that projects have three main phases: Getting Started, Main Part, and Culmination, although these phases have been given different labels. Three critical management strategies must be used throughout the project: (a) conducting whole-group discussions, (b) documenting phases, (c) remaining flexible yet organized, and (d) focusing on concepts.

Also, be open-minded about the "mess" projects can create. The messiness can make project work appear chaotic, and indeed, it can be if teachers do not have general plans and management strategies in place. Given a chance, however, projects reveal their own structure and organization. In other words, there really is a method to the madness, although it may not seem so at the outset. Ironically, children create structure and organization almost naturally. They see the potential in projects, and rarely notice the mess. In fact, it is in the apparent mess and chaos that children encounter their most valuable learning opportunities!

Phase One: Getting Started

Phase one involves the groundwork, the beginning and focusing of the project. Therefore, you will notice that considerable amount of *basic* preparation and organization occur during this phase. Phase one requires the most work on the teacher's part. Some work excludes the children, such as collecting boxes from stores and scheduling trips and speakers. Other work includes the children, such as gathering odds-and-ends from their homes and determining a specific focus.

An important first step is to determine a topic (see chapters by Allison and Thomas, Section One). Next, create a project web with children (see Smith & Nassingar-Barr, and Eckerty & Allison, Section Four). Start by brainstorming to find out what they know about a topic.

Write down their ideas on a large paper at group time. Then, categorize ideas. From there, make a project web to establish a focus. You can add to the web other concepts about which children want to know.

The next step is to assign roles and responsibilities with the children. For instance, the children may want to know about the *construction site* next to the school. The project web has in its center: "CONSTRUCTION SITE: WHAT HAPPENS THERE?" Radiating outward from the center are concepts, about which children want to know, that are posed as questions: What Do People Do? What Holds the Construction Site Together? and so forth. Children work individually or with others to investigate particular questions and concepts. This investigation informs children about how to design and make a "construction site" in the classroom.

Phase Two: Main Part

Phase two of the project is full action. By now, much attention has been given to the focus of the project, and investigations continue. The main activity now is to demonstrate what children know. This results in a construction, or artifact, of some sort: a building for a post office, a model of a river, science laboratory, a house, a mural, or something similar. Much more detail in children's learning is demonstrated at this point. A developed knowledge base results in three main events that can occur simultaneously: (a) children refine the project, (b) they use their constructions for role play, and (c) they add a new focus that can shift the project (e.g., a post office to serve the construction site).

Phase Three: Culmination

As indicated, phase three usually involves a shift in the project's direction. It can take on a related, but different, direction. Or, it can be concluded altogether. In a related direction, children add a new, complementary project. This is beneficial because children can work on the original project or create a new one based on their learning progress. In this case, the teacher guides children into a new, related project that is based on the original one. Be prepared for more role playing, discussions, and additional assessments.

When children choose to conclude a project, the teacher and children together decide what to do. Should we deconstruct it and take pieces home? Should we use the structure for another project? Should we not have a project for a while? Note that there is much learning potential in the process of deconstructing the project. Children revisit skills and knowledge they encountered during its construction.

Regardless of the project outcome, celebration is crucial to the project's conclusion. Children can, for instance, use the "house" for a birthday party. Parents and other children can visit the project as children explain its development. On a larger scale, teachers can have their children demonstrate their projects during a school project fair.

For more information about project webs, projects, and responsibilities, see Hartman and Eckerty, (1995), Katz and Chard (1989), and Wortham (1994). Of course, Section Four offers useful tips about project implementation.

Physical and Human Environments for Projects

Projects exist within human and physical environments that support their development. Without appropriate support, projects could have short lives, and be frustrating. While viewing the *physical* environment, one would observe a classroom that departs from traditional arrangements. Instead, the classroom is a place where many environments exist within a larger environment, all of which support children's inquiry. For example, activity series and centers, and projects benefit from a classroom that connects to the community. The classroom can serve as:

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> Part museum, publishing house, think tank, writers' workshop, artists' studio, theater, drafting room, computer lab, library, bookstore, gallery, recording studio, and more. As a result, the teacher's role becomes that of curator, impresario, editor, futurist, therapist, director, producer, media resource specialist, salesperson, and engineer. (Hartman & Allison, 1996, p. 15)

Upon observing the *human* environment where projects develop, one would see that children and teachers have fairly equal roles. Because projects usually stem from children's interests, the teacher follows the children's lead as much as possible. Yet, the teacher still has discretion as to what is deemed relevant to attaining overall program and project goals. In this democratic process, teachers do not give up control to children. Rather, they include children in the decision-making process so that children have some ownership in the learning process.

Teacher Roles

The teacher has many roles, all of which are supportive of children's inquiry. These roles are, for instance, acting as a coach, a supervisor, a monitor, and a consultant. Children, too, can perform these roles with each other, either in teams or a large group. Teachers also are a liaison between children and the outside world.

Community Roles

In addition to the supportive roles of the teacher, people in the community also assist children in their inquiry. Community connections are a central trademark of project and broaden the contexts in which children situate their inquiry. Initially, the classroom serves as a "home base" from which other environments and events are examined.

Children's Roles

At first glance, children's *activity* during project work may appear chaotic. To the contrary, children's activity—or inquiry—during project work is meant to be focused and scientific. Depending on children's ages and developmental needs, they conduct research and ask questions to understand their topics. The processes used during inquiry involve: posing questions, establishing data collection responsibilities, examining various data sources, constructing meaning from data, and representing the meaning in artifacts. The artifacts can include created environments and objects, murals, artwork, journals, and role playing activities. Finally, children are taken seriously in the human environment. Learning involves educating children's minds as well as their hearts.

Balance and Flexibility: Teachers and Children Working Together

There are different opinions as to how much adult direction children need to learn optimally during their inquiry. Increasingly, research and practice show that children need a balance of child- and adult-determined learning opportunities. Perhaps the balance results from *guided inquiry*—a "middle-of-the-road" approach that combines student interest and teacher discretion (Hartman, DeCicco, & Griffin, 1994; Allison, in press). Teachers need not give up control in the classroom; they include children in that control.

Both physical and human environments treat learning as a process. Consequently, these environments change over time as a result of new understandings children gain from their inquiry (McLean, 1995). The key to inquiry is to keep children in the forefront of the learning process.

Topic Selection

One way to keep children in the forefront of the learning process is to choose topics that match their interests. The more personal a topic is to children, the more readily they will invest it. On the other hand, the less personally a topic is associated with children's lives, the less easily they will relate to it.

Choosing Topics

Teachers can select relevant topics by asking open-ended questions (e.g., How are houses built?), or basing topics on children's curiosities revealed during their conversations with other children and responses to events. Choosing the most desirable topics can be a bit tricky at times. Children do not always reveal their interests, and some children will have different opinions as to what should be investigated. At times, the teacher may have to capitalize on a relevant event or environment in which the children have not taken a direct interest (see Eckerty & Allison, Section Four). Strategies become easier as teachers get to know children (Hartman & Eckerty, 1995).

Focusing on Meaning

Teachers are advised to consider topics that focus on meaning (see Thomas, Section One). Meaningful topics often are: (a) accessible, (b) concept-driven, (c) generative, (d) useful, and (e) complex. Topics may show some or all of these characteristics. One of the most important characteristics of good topics to consider is their *accessibility*. Topics that allow children to *directly* inquire about their environments are the *most desirable*. Children benefit greatly from first-hand experience throughout a project's entirety. They also must have repeated encounters with phenomena.

Good topics help children focus on *concepts* in learning, such as underlying meaning. For example, instead of studying "pets" randomly, children begin by studying the concept that "people take care of pets." Focusing on concepts puts children in contact with ideas, messages, and experiences they can readily understand, rather than those that are too advanced. Once children develop a knowledge base about these things, they can add *complexity* and depth to their learning. As children progress in project work, they can *generate* more knowledge that is *useful*.

It is true that methods of choosing topics vary. Some topics will be more child-based, and follow children's spontaneous interests; others will develop from a teacher's knowledge base and align closely with the school's agendas. Some topics will be both child- and teacher-based. Remember, topics must relate to children's lives (see Section One).

Resources for Projects

Projects can seem ominous, especially when considering the resources they require. Are projects expensive? Does a teacher need extensive materials? The best resources are those that are *free!* Yes, free and plain. Authentic, real, simple objects and people in life are the very things toward which children gravitate. Ironically, adults choose more expensive, decorative, and socially-appealing resources. If given a choice, however, children would rather add the glitz and glamour to resources on their own. So, try to avoid prefabricated items.

In other words, part of learning for children is in the process of making their own props. For example, children love to take plain boxes and glue them together to represent something such as a "house." Furthermore, they like to cut wallpaper out of the sample books and decorate their houses' interior walls. They even use large styrofoam pieces as fluorescent lights. It is through the "realness" of constructions that children demonstrate best their knowledge, skills, and creativity.

Collecting Resources

Resources to collect are boxes, especially large ones; samples of wallpaper, carpet, cloth, textiles, etc.; glue, tape, string, etc.; paints, markers, and crayons; safe recycled products such as paper, styrofoam, paper product rolls, food containers; and all types of odds-and-ends. You will need enough resources to carry children through at least two projects, because one project often leads to another. Storing resources becomes a challenge in this process. Teachers have used any available space they can get their hands on! Some have "borrowed" space from another classroom. And then, there are special places to find and store resources specifically for science and mathematics (see Sullenger & Holland, Section One, and Brophy et al., Section Four).

Finding Resources

Places to find resources are everywhere, especially in stores for appliances, cloth and crafts, and businesses. Parents, children, teachers, and neighbors are excellent resources, both for collecting desirable items and for sharing personal skills. A parent, for instance, can demonstrate how to make tortillas following a field trip to a tortilla factory. An older student can visit your class and share some history about tortillas. A local children's book author can visit the children and share his or her experience writing a book about tortillas. The possibilities for resources are inexpensive and endless. You will need to scrounge everywhere you can think of, including alleys behind stores (e.g., throw-away boxes). Remember, to children, the best resources are free and simple.

Assessing a Project's Effectiveness

There are various ways to assess a project's effectiveness (see Sullenger & Holland, Section One, and Smith & Nassingar-Barr, Section Four). The most popular method is portfolio assessment, because it is consistent with the artifacts children create that demonstrate knowledge and skills. Common portfolio contents include samples of writing (required and introspective), work products, photographs, research notes, essay quizzes, and "think" sheets.

Some teachers supplement portfolios with standardized test results. Although we do not advocate the use of standardized testing, it is interesting that some teachers report positive scores when projects have been part of the curriculum (Hartman, DeCicco, & Griffin, 1994). The test portions with which children perform especially well are those that require reflective thought and problem solving, both skills being central to project work.

Assessment of project work must occur throughout the project, as well as with a culminating activity (i.e., formative and summative evaluation). The best assessment pieces surface during all phases of the project. Remember, it is *progress* that a teacher documents. Progressive evidence shows academic growth over time. And, this evidence is cumulative from one project to another so that a series of project work samples create the portfolio.

Comparing Thematic Units and Projects

To understand what projects are, it is useful to understand what they are *not*. I take a risk by distinguishing projects from other related approaches, such as thematic units, because the two approaches share similarities, yet they have uniquenesses. Projects and thematic units have similar facets to their approach. Similarities include: use of activity series and centers, curriculum integration, a common theme or topic, complementary experiences such as field trips, and the acquisition of skills and knowledge. Although similar, thematic units are still unique from projects.

There are advantages to thematic unit teaching. Many teachers can follow the same unit across grades, with different twists to the unit. The unit can be expanded upon year after year. And the unit can be easily aligned with more traditional objectives that meet larger program or districts standards. One main advantage of unit teaching is with the obvious structure and predictability some teachers prefer. Unit teaching can be a stepping stone to more open-ended approaches like project work.

The Focus of Unit Teaching

Even with its apparent advantages, too much thematic unit teaching can overemphasize:

- Activities *rather than children in a learning process* (e.g., more time is devoted to appearance rather than the value of what children do).
- Entertainment *rather than engagement during learning* (e.g., having "fun", exciting children).
- *Terminal teaching and learning* (e.g., topics that "end" at a certain time; topics that children cannot "shift" in direction).
- External *conditions and limitations* (e.g., district goals, restrictions on field trips).

Even with the best intentions in mind, adult agendas drive the focus and activity of thematic unit teaching. Usually, thematic topics are pre-established ahead of time by teachers, and these topics are covered similarly each year. Furthermore, thematic topics can result in tasks that have pre-destined ending times with set time frames and goals.

Conclusion

Earlier, we called for a focus on children as central to the learning process. Refocusing on children is not easy, unfortunately. Teachers often juggle children's needs with increasing public pressure to increase test scores (Rosenholtz, 1989). The good news is that the project approach provides a wonderful avenue to balance diverse demands. Projects blend different approaches to learning, and allow children to apply skills and knowledge they need to function well with both informal and formal education (Hartman & Eckerty, 1995). Projects can be a way to integrate activity series and centers as well (see Rillero in Section Five).

Increasingly, educators are providing programs that are responsive, that is, appropriate and adaptable to diverse populations. This response has been influenced by the many position statements of leading educational organizations concerning appropriate practices. Added to these position statements is the reality that educators must serve a diverse population. Educators, therefore, need to be culturally responsive as well. How can educators best provide appropriate practices? One way is with projects. Educators have used many forms of project work in educational programs for years. Other approaches may come and go, but student-responsive educators continue to advocate for project-type curriculum across ages and stages of learning.

Preview of Section Four Projects

The projects in Section Two highlight science and mathematics learning, while still including other content areas. These projects also ascribe closely to appropriate practices in North American and internationally (Bredekamp, 1987; Spodek, 1991), and exemplify how teachers can keep children in the forefront of their learning. The projects show teachers how to build curriculum around *children's* interests and personal backgrounds, and the projects accommodate all types of learners, both with regard to learning capabilities and geographical locations.

The learning process is interactive; there is a balance between individual-, peer-, and adult-directed learning. The authors also note that there are challenges associated with project work, just as there are challenges to face with everything we do. Our first challenge is ourselves, as teachers, according to Eckerty and Allison (Section Four). When trying new practices, teachers can be naturally skeptical. Discretion should be used when sizing-up the value of any method we offer to children, but our problem sometimes lies in being too skeptical, however, to the point that children lose out on learning approaches that suit their needs. As Granse points out in this section, these challenges are common among constructivist approaches to learning, yet, the rewards overcome any obstacles. Play with the ideas presented in these projects.

Think about what parts could be adapted in your teaching. You may want to try a project as closely as presented by an author. Or, you might decide to develop one particular aspect of a project with activity series and centers. You might want to try projects with older students (Allison & DeCicco, in press). The important point to remember is that the projects in this section are not recipes. They are examples that worked well for the people involved in them—so well, that the authors encourage you to give projects a try.

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Chapter 16

Learning About Spiders in an Australian Pre-K Class

Ann Smith & Angela Barr

This chapter describes the progress of a successful science project on spiders in a pre-kindergarten class of twenty children, four and five years old. This project lasted eight weeks and emerged out of the teacher's considerable fear of spiders. It was carried out jointly by the two authors and an assistant teacher—all referred to in the chapter as "the teachers".

Initially, this effort began as a small-group project. However, interest was so widespread among children that the small-group project turned into a whole-group project. While the central focus of the project was science, considerable mathematics and other content-area learning also took place. The mathematics learning is discussed throughout this chapter, though it is not treated in the same depth as science learning.

The framework for this project resembles very closely the framework outlined by Katz and Chard (1989). Just as all projects have their unique features, ours likewise was distinctive in its focus. We describe the following features of our project:

- Children's involvement in helping the teacher overcome her fear of spiders.
- The emergent curriculum viewpoint that led to children's interests, pointing the way in an ongoing program.
- The extensive documentation of the project, particularly interviews conducted with each child.
- The use of games as teaching strategies and learning opportunities.

The topic was appropriate because the teacher, Angela, had a real fear of spiders. The children were very much aware of this. Children and the teacher, therefore, had an affective investment in this topic. Here is how 5 year old Emma described her teacher's reaction to a plastic spider during a home visit.

> And I said close your eyes Angela 'cos I went round and I put it [the plastic spider] on her lap and she screamed...she was frightened of mine. She said 'please keep it away.' She had tears in her eyes.

Andrew too, like the rest of the children in the class, was aware of his teacher's fear of spiders. He said, "I'll tell you a story. I gave Rae a woolly jumping spider for her birthday and she brought it in [to pre-school] and she made it jump, she made it jump and Angela got so frightened." In light of the strong interest expressed by the children and teacher, the topic of "spiders" was selected.

The Project

Phase I: Getting Started

The teachers started with an initial brainstorming session. They discussed ways of introducing the topic to the children and ways of gauging if the interest was likely to sustain an in-depth project. Basic scientific concepts to be used as a framework for this investigation were also discussed by the teachers, though the team felt strongly that it was important to be flexible and go where the children's interests led. The basic scientific concepts that the teachers had in mind were those that made spiders unique. These were:

- Body structure.
- Use of silk.
- Use of poison.
- The spider life cycle.
- The differences between spiders and other small invertebrates, particularly insects.

As the project was primarily to explore spiders in a scientific way, teachers were content to promote mathematics learning by following up on, and strengthening, the mathematics concepts they felt would inevitably arise.

Because of her very real fear of spiders, it was agreed that Angela would start by handling the more theoretical aspects of the project and the other teachers would look after any specimens involved. In order to decide which children, if any, were interested in pursuing this topic, children working in small groups were invited to draw spiders and talk in an open-ended way about their experiences with spiders. Predictably, most of the drawings were of a creative rather than a scientific nature and webs were traditional orb (wheel) webs.

During the discussion, stories about Angela's fear of spiders and stories about spiders in mail boxes and cars were common. Some of the boys talked about the fictional "Spiderman." A few children talked about TV programs they had seen or books on spiders they had read.

A fascination with poisonous spiders, particularly Red-back spiders, was clearly evident. The Red-back (*Latrodectus hasseltii*) is a relative of the American black widow spider and is the only potentially lethal spider in the Melbourne area (Walker, 1993). It is, however, unlikely to be seen in houses as it seldom leaves its web. Many people have never encountered one. Anti-venoms are readily available, and the last recorded death was in 1956. This spider has acquired a high profile in the Australian imagination as the children's comments show.

Andrew: "Red-backs are poisonous."
Nathan: "Yeah."
Hugh: "Daddy long legs aren't."
Andrew: "Are!"
Hugh: "Are not!"
Andrew: "Are!"
Hugh: "Are not!"
Andrew: "Daddy long legs are the poisonest spiders in the world but they can't bite you because.."
Nathan: "No Red-backs are the poisonest."
Andrew: "No Daddy long legs are but they can't bite you."
Teacher: "Could we write that down as one of our first questions?"

Teachers judged from the small group discussions that a substantial interest did exist in the topic. When asked if they would like to learn more about spiders, the children responded positively and enthusiastically.

Early Interviews

One approach teachers used to gain insight into the children's level of understanding was to talk with each child. Children were very used to having their ideas listened to and documented by adults, so when the teacher asked if she could interview each of them individually for a few minutes during outdoor play time, the children were eager to be involved. These interviews occurred over the next few days. Children were asked, "What is a spider?" and " Are spiders dangerous?" and on another occasion, "How could we find out more about spiders?"

In response to the first question, a few children said it was an animal or a creature or even an insect. Many referred to it as something with eight legs and several named specific types of spiders. When the teacher asked them if spiders were dangerous, all the children said that at least some were. The preoccupation with Red-backs was still clearly evident—17 out of 20 children mentioned them—for instance:

Teacher: "What is a spider?"

Chrissy: "It's dangerous. Spiders are Daddy long legs. If you touch them they just crawl away."

Teacher: "What does a spider look like?"

Chrissy: "Legs, not our legs. It has eyes, mouth. It has babies."

Teacher: "Which spiders are dangerous?"

Chrissy: "Red-backs."

Teacher: "What is a spider?"

Jane: "A spider."

Teacher: "What does a spider look like?"

Jane. "Dot, legs, legs."

Teacher: "How many legs?"

Jane: "Don't know."

Teacher: "What's a web?"

Jane: "I don't know, oh yea, it's made of silk."

Some children gave more sophisticated answers:

Teacher: "What is a spider?"

Maree: "It's not an insect. It catches insects."

Teacher: "What does a spider look like?"

Maree: "It's got eight legs and a body."

Teacher: "Are spiders dangerous?"

Maree: "Lots of them are but Daddy long legs aren't."

Teacher: "Which ones are dangerous?"

Maree: "Red-backs —really dangerous—you can't touch them."

In response to the question, "How can we find out more about spiders?" predictably most children said we should look at the real thing (14 out of 20 children).

> "Explore spiders to see what they're like—with a net. Catch them in a net or a bug catcher. Touch it and see what they feel like."
>
> "Find them in the country. (country—a colloquial expression for a rural area) Remember what they look like. Take photos of them."
>
> "We should catch a really large one and a really small one. A male one and a female one."

Two children suggested looking at models.

"I have a toy spider at home."

"By looking at a plastic spider."

Only four children suggested asking for outside help. Some of these replies showed a high degree of awareness of sources available.

"Ask somebody. Think about it."

"Go to a school. See their webs. Go to a zoo to see spiders—or university."

" The bug museum. Ask someone who knows about spiders.

"Ring up 'Our House' (a television program) 'cos they've caught Funnel Webs." (Funnel Webs are highly poisonous spiders not found in this locality.)

Only one child mentioned using books as a resource, which was surprising as they spontaneously used this method of learning throughout the project.

"Ask Ann about spiders. Go to her house. She could lend us her books and we could read them."

The ideas gleaned in the interviews, along with the initial children's discussions and the teachers' notions of relevant areas of investigation, began to shape the program. A project web was drawn up. This grew out of discussion between the three teachers. It included the basic scientific concepts. It also listed possible resources and possible creative and affective aspects of the project relating to dance, drama, art, fiction stories and so on. It served as a general organizational framework for the teachers, which could be added to at any time.

Parents were informed about the project and asked to let the teachers know about any fear of spiders their child may have now or during the project. The teachers assembled resource materials—mainly in the form of some simple reference books, appropriate fiction stories and good quality posters.

An area of the classroom was set aside where material relating to the project could be displayed or stored and where a table allowed for small group work and discussion. The children's initial drawings and some of the teachers' posters were the first things to be displayed. Children needed little encouragement to look for webs and spiders in the playground. An organization of the project is presented in Figure 16.1

Phase II: The Project in Progress

No strict timetable for the project was set out. Many other things were happening in this busy class. .The children enjoyed a wide range of traditional pre-school activities such as block play, dramatic play, construction activities, art, music, dance, group discussions, field trips, outdoor play, and celebration of birthdays and holidays. On most days, however, there was some reference to spiders—often of an informal nature—and on at least two or three days of the week the teachers introduced some spider-focused activity or discussion either with the whole class or a small group.

Approaches to Learning

Many approaches were used. One basic approach to the teaching and learning process was to respond to and extend the children's existing knowledge, ideas, and questions about spiders. At the same time, teachers kept in mind the list of scientific concepts nominated earlier in this chapter.

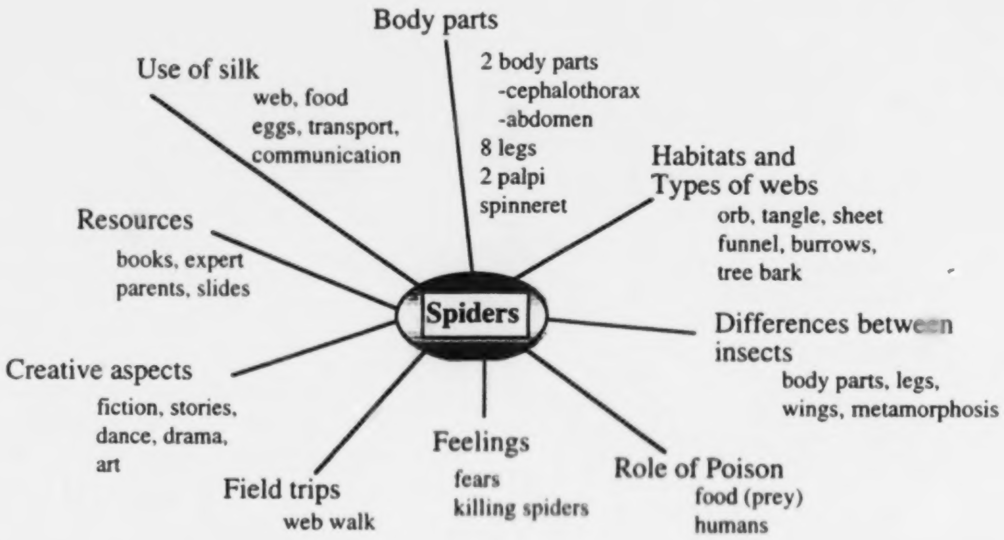

Body parts
2 body parts
-cephalothorax
-abdomen
8 legs
2 palpi
spinneret
Use of silk
web, food
eggs, transport,
communication
Habitats and
Types of webs
orb, tangle, sheet
funnel, burrows,
tree bark
Resources
books, expert
parents, slides
Spiders
Differences between
insects
body parts, legs,
wings, metamorphosis
Creative aspects
fiction, stories,
dance, drama,
art
Feelings
fears
killing spiders
Role of Poison
food (prey)
humans
Field trips
web walk

Figure 16.1 *The Spider Project Web*

Teachers also believed strongly in a multi-symbolic approach because children learn in many different ways. Children were given the opportunity to express themselves in words, drawings, paintings, models, dance, and dramatic play. They explored spiders through live specimens, plastic models, field trips, games, and creative as well as scientific books. Working within the freedom of a pre-school setting with a teacher, an assistant teacher and a part-time researcher allowed for a very flexible and almost informal approach.

The teachers believed that the children would be more motivated if it was suggested they were studying spiders in order to teach others about them. This notion was presented to a small group of children. While the children were certainly interested in the idea, it soon became evident that they did not need this sort of goal or extrinsic motivation. Rather, they were motivated by the learning itself and by being part of a group, a community that was undertaking a project. Katz and Chard (1989, p. 6) explain the value of a "community ethos" in the class. The Reggio Emilia educators call it a sense of "we." "The actual theme or content of the project is not as important as the process of children thinking, feeling, working, and progressing together with others" (Rankin, 1994, p. 194).

Later, there was a very important occasion on which the children could share their achievements with their parents, but this was more in the form of a celebration, a conclusion to the project than a motivating factor in itself.

The Use of Discussion

One basic teaching strategy used here with these largely pre-literate children was discussion: small group discussion, discussions with individual children, and whole class discussion. Discussion allowed teachers to understand the children's existing level of knowledge, their ideas and feelings, their areas of interest, as well as their misconceptions. It allowed the teachers to shape the program to suit the group. Material could be introduced to fit in with a student's or children's interests. In particular, much discussion and future program direction came out of the books and specimens that the children contributed. Aspects that children had explored in small group discussions could be shared in large group time.

Expert's Visit

As reported earlier, some children had talked about going to an outside source in order to find out more about spiders. At the teacher's suggestion, the class wrote a letter to the curator of invertebrates at the museum of the State of Victoria. They asked if he would come and talk to them about spiders. Children helped decide on the words to go in the letter and a few of the children copied them. All the children drew a picture of a spider or web on the page or envelope.

A wonderful visit followed with slides, specimens, and a live giant South American tarantula called Cuddles! This was a rare treat for the children and adults alike because there are no tarantulas of any sort in Australia. The children were particularly interested in the story of how Cuddles was smuggled illegally into the country. They commented on how hairy she was and asked why there was a cricket in the glass cage with her—her next meal!

Before the visit, the teacher interviewed each child and recorded one of their questions about spiders to ask the expert. These were varied and reflected the children's genuine interests and concerns, for example:

> "Angela used to be scared of spiders. How can we stop Angela from not being scared?"
>
> "Are spiders dangerous?"
>
> "Are Red-back spiders poisonous?"
>
> "Are spiders black?"
>
> "Do spiders like to go in their webs?"
>
> "Why does the girl spider eat the boy spider? Is it tasty?"
>
> "How do you know if it's a boy or a girl?"
>
> "How do spiders get web in their body to make a web?"

Children's and Parents' Contributions

Right from the start, the children (and indirectly their parents) took over some of the project's direction. The children began bringing in plastic spiders and other small plastic invertebrates such as insects. They brought in many books. These ranged from adult level reference texts to cartoon level books with quite anatomically incorrect depictions of spiders. Some children also brought story tapes and song tapes. All contributors were welcomed and used in a positive way. Even the most unscientific or inappropriate representations of spiders were the basis of meaningful discussions. The plastic spiders and insects turned out to be quite accurate in a basic anatomical sense, so they were useful teaching tools.

A few children were taken to their local library by their parents to look for spider books. Rachel reported that there were 20 books about spiders on the computer catalog and 100 on the shelf. Fiona was excited to find a book written by our visitor from the museum in the computer catalogue, but was disappointed that it was not on the shelf.

Another child brought in the book, *Charlotte's Web* (White, 1963). The teacher read one chapter each day to the children. Such a long book with so few illustrations requires a degree of concentration that is not easily sustained by children of this age. However, the fact that many of the children had already seen the video at home made this a successful exercise.

Reading this book led to good discussions about scientific versus creative ways of writing about animals, and the merits of each type of writing. Later each child dictated a creative spider story to the teacher to make a class storybook

Along with facilitating the children's contributions, parents helped in other ways. They often chatted informally about spiders or their children's interest in the project. One mother wrote down the detailed discussion at home with her daughter following the museum curator's visit. She brought this into the teachers along with Jenny's drawings. This was very encouraging as it showed how interested Jenny had been. It also allowed the teachers to pick up one misconception that had occurred. It was clear from the drawings and the words her mother had recorded that Jenny believed that only male spiders had palps. (Palps are the short leg-like appendages on the front of the spider used to manipulate food and other material.)

Children also started to bring in live specimens, including spiders, insects, lizards, etc., as well as a large supply of the nymph "shells" left on tree trunks by newly emerged adult cicadas. Children were asked to take all live specimens back home at the end of the day and release them where they had been found. Bringing in specimens also allowed teachers to discuss safety aspects.

The general message was "almost all spiders are harmless to humans, but one or two could give you a painful bite or actually be poisonous—so it's much better to observe the spider in its natural setting. If you want to bring it to pre-school, then ask an adult before you handle it." The fact that children could do a lot of harm to a small fragile spider was also pointed out. The teachers and the visiting expert stressed that we don't need to be scared of spiders. They are not going to jump on us. The visiting expert said, "We do need to respect them. It's the same as if you handle a cat or dog roughly. It will scratch or bite you in an effort to protect itself." Rachel, one of the children, summed it up, "If you don't hurt it won't hurt you."

Use of Games

Games proved to be important teaching/ learning tools. In one instance an initial group read a book that was a small and inexpensive sticker book produced by an environmental education organization for elementary school children (Gould League of Victoria, 1988). Two things in it really did "engage the children's minds." One of these was a game which the children asked to play. (The other was a series of diagrams which showed the construction of a wheel web by a spider.)

The game was a simple one: Animals could move one square at a time and either eat or be eaten by the other animals. The aim was to try to get the spider successfully across the board to its web. The game introduced the children to spider predators and prey. It started an interest in games that was maintained throughout the project.

The teachers used games as a direct way of teaching and reinforcing many of the scientific concepts relating to spiders. At the same time skills involved in social interaction, logical thinking, problem solving, language, mathematics, and motor coordination were constantly being practiced by the children. Such is the wonderful integrated nature of the project approach. It is, however, the science learning and to a lesser extent the mathematics learning that are the foci of this chapter and will be discussed here. Children explored the following concepts:

- Predator prey relationships of spiders.
- Life cycle.
- Broad environmental needs of spiders.
- Body structure.
- Various uses of silk in trapping prey.

They also practiced mathematics skills that related to:

- Counting.
- Measuring.
- Sequencing.
- Recognizing and writing numerals.
- Matching quantities with numerals.
- Adding.
- Subtracting.

A Teacher-Made Board Game

Following on from the children's understanding of the first game, teachers planned a more complex board game to bring out aspects of the life cycle of spiders. The life cycle concept was chosen because it incorporated many of the aspects that make spiders unique. In this game, children started with a team of spiderlings—usually six, which ballooned away on their length of silk and met realistic situations such as predators, insecticides, weather problems, and food shortages. Some survived the whims of humans and nature long enough to mate and lay eggs.

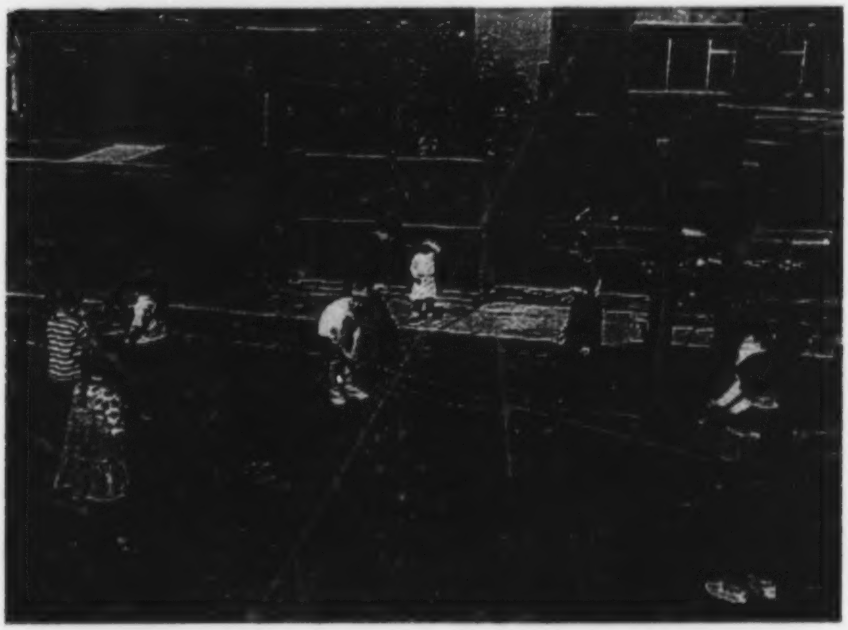
In terms of mathematics, children practiced skills such as:

- Recognizing the numerals on the die.
- Matching these numerals into the number of squares they could move on the game board.
- Representing the correct number of baby spiders in their team—(usually they did this by drawing a picture of each one of the spiders.)
- Carrying out subtraction by crossing out some of these spiders as they died.
- Carrying out addition by adding more spiders when the eggs hatched.
- Practicing sequencing concepts as they took turns to play the game in a set order.

Building a Spider Game

Soon after the visit of the museum expert, teachers introduced a game to "build" spiders on individual felt boards. This was a version of the traditional "insects" or "cootie" game. A throw of the die wins the player body parts made of felt—legs, palps, or an abdomen, etc. Children were equally comfortable using a die with colored spots or one with numerals on it. Three different spiders were used. The children were familiar with the three that were chosen. Each had a different habitat and life style.

A Red-back was chosen because of the children's interest and because it makes a web. A Huntsmen (*Isopeda montana*) was chosen because two specimens had been brought in and because it doesn't make a web but lives under the bark of trees. Finally the teachers overcame their resistance to using non-native spiders and included Cuddles the Tarantula. Tarantulas often live in a burrow in the ground. Children also had to win a card with the correct habitat pictured on it to complete the game. Mathematics learning in this game focused mainly on children recognizing the numerals on the die and adding the correct number of legs to their spiders.



Web Games

Other games were introduced which could be played outdoors. A simple game was designed to explore the concept that web spinning spiders don't have good sight but rely on feeling vibrations to capture their prey. This proved to be popular over a long period of time. One child stands in the middle holding several pieces of yarn or string radiating out from her. Children hold the other ends six or eight feet away. The child in the middle has to close her eyes and "feel" the vibrations as one child shakes her piece of yarn. When the "spider" points to the correct "insect," that child can be the spider.

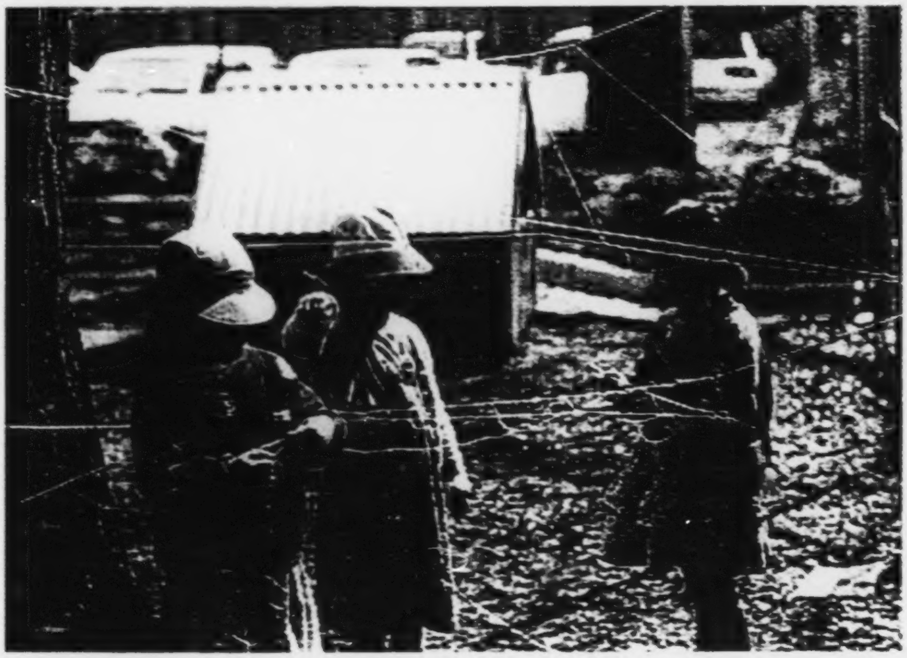
On another occasion, teachers introduced a game that helped children see the variety of ways spiders use silk to catch their prey. One of the books had described a group of spiders which attract an insect, often a moth, then let down a length of silk with a sticky blob on the end which they swing around to capture their prey. They are referred to as Bolas spiders. A paper spider on the end of a ruler had a thread with a blob of sticky tape on the bottom. The aim of the game was to hold the ruler and have the "spider" catch several moths (small pieces of Kleenex tissue). Children were usually motivated to count the number of moths their spider had caught. This game seemed to appeal to some children who had not been interested in the board games. To extend the idea, children were also shown a picture of net casting spiders (several species) which drop a small net of silk right over their prey.

Traditional Games with a Spider Emphasis

Some games were variations of traditional games. Spider "hopscotch" involved the children walking, jumping, and hopping across a "web" marked on the ground with the child being able to only stand on the non sticky strands. This game evolved from the question of why a spider doesn't get caught in its own web. As a further variation, children were sometimes told that this was the web of a Black house spider (*Xeuticus robustus*). Then they were allowed to stand on all strands of the web but had to move faster. The children had seen some Black house spiders on a rotunda on their walks. It has no sticky strands in its web and relies on its speed to get the tangled prey.

"What's the time Mrs. Spider?" (based on What's the time Mr. Wolf ?) was another physically active game that brought out the simple spider and prey relationship. The game was played in the usual way whereby the insects asks the time and the spider replies, "one o'clock, two o'clock," etc. and when she says, "dinner time" she chases the other children. The child that is caught then becomes the "spider." (Older children could play the game by nominating a particular insect and then reading the labels on the children's backs to catch the correct one.)

A simple bean bag toss game involved several diverse skills. Four children really enjoyed making the "web" out of string between a large tree and the wire mesh fence. Other children filled tiny cloth bags with grains of rice having first drawn an insect or another spider on the outside of the bag. Two children sewed the tops of the bags to close them when staples proved inadequate. Rules and the aim of the game had to be established. Did players have to throw the bags under, over, or through the "web"? Where would players stand to throw? Would there be a penalty for the bags that were thrown into the tree?



Teachers wrote out the rules dictated by the children. When the children decided to make this one of the games for the spider night party, the rules were made even more formal. The distances were measured and written down to define where players could stand. The concept of handicapping also emerged. The children decided that younger siblings could stand close; fathers had to kneel down to throw, while mothers could stand up.

Quiz Games

Quiz games proved to be something all the children were able to enjoy and, after a little practice, participate in. The type that starts, "I am thinking of an animal. It has..." These quizzes related to all animals, not just spiders. They allowed children to focus on aspects that make a particular animal unique both in terms of appearance and life style. They ranged from, "I am thinking of an animal that has two body parts, eight eyes, eight legs, it doesn't spin a web and it got caught by Heidie's dad in a vacuum cleaner," to "I am thinking of a bird that is black and white, it can't fly, and it lives at the south pole." Children often asked to play the quiz game at group time. All children elected to make up a quiz for parents to try at the spider night party. The quiz question was written on the outside of a manila folder while the answer and a picture of the animal, drawn by the child, was inside.

Child-Designed Games

Children were also enthusiastic about designing their own original games. Some made board games, while others made jigsaw puzzles. To follow the process of the children creating their own board games would be a worthwhile study in itself. Any adult who has tried to design such a game will know how challenging this process is. At the developmental level of a four or five year old the process is challenging indeed.

A teacher needed to work with only one or two children while they were making their games. She needed to help them to think about the process they were engaged in. This very intensive adult involvement would not be possible in all classes. Some of the key aspects that emerged are discussed next.

Some children had to be helped to see that they needed a goal or end point to the game; others needed help deciding what this end point would be. Usually children wanted to play their game before rules had been established. The teacher asked questions to direct the student's thinking. for example, "How do I know if I've finished the game?" "What does Edward have to do to get to the end of the game?" Answers were often global in nature. For example, "You go round and round the web like this and then you get to here you win and eat your dinner." Questions from the teacher gradually helped the child divide the whole task into steps of a game. "How far do I go on my first turn?" "What tells me how far to go?" "Can I throw a die to tell me?"

Because of the egocentric nature of children at this stage of development, they very often made up rules that advantaged themselves and disadvantaged their opponent. "When I throw a '2' it means I go to here, when you throw a '2' you have to miss a turn." Usually another child would object and decline to play; however, if this didn't happen the teacher insisted on the same treatment for all. Children had to use many of the mathematical skills listed earlier when planning and playing their game. Usually the child making the game was helped by one or two other children. Often they were drawing, cutting, coloring, making suggestions or perhaps making a die.

One important feature was the similarity of the children's games to those that the teachers had introduced. It clearly demonstrated that modeling is a very powerful aspect of the learning process with young children. Many of the children's games were based on a predator/prey relationship and used a die. There was, however, a great amount of diversity within this framework.

Keeping Spiders

While games dealt with spiders in a symbolic way, teachers also wanted the children to have the more concrete experience of observing real spiders. Children were encouraged to look for webs and spiders in the playground and were taken on walks to do this in a more natural setting.

Teachers wanted the children to understand the importance of not taking animals out of their own environments, and, when animals are collected for study, the importance of returning them to their own habitats as soon as possible. However, as spiders were a little hard to observe in their natural habitat in the daytime and at this time of year, some attempts were made to keep spiders in the classroom for a couple of days.

Spiders are hard to keep because they require live food. Small humped spiders (species unknown) were set up on twigs in a container that was placed in a larger container filled with water. Small slaters were introduced, and fruit flies were attracted to ripe fruit placed nearby. Neither the slaters nor the flies seemed to tempt the spiders' appetites.

The spiders were left outside for the night so they could catch their own food. By morning they had all made their escape. During the day, however, children had been able to observe spiders spinning silk threads between the twigs and dropping down on their lines of silk. One more attempt was made to keep a small garden spider (species unknown) brought in by one of the children. The results were the same.

Web Walks

The project commenced in the winter term, which meant there were less spiders to be seen than at other times of the year. Late summer is the best time. The teachers and children went on regular web walks in a nearby unused convent garden. On one of the early walks, children were encouraged to draw webs and any spiders they saw. This allowed the teachers to introduce the idea that there were different types of webs. This was reinforced back in the classroom with clear pictures from a junior science text that one of the children had brought to preschool.

None of the traditional orb webs was found on this early walk, though interestingly enough, some children still drew the webs this way. This allowed the teachers to encourage more careful observation and talk about how scientists have to accurately record what they see.

Another question raised by these early walks was, "Where are the spiders?" Webs were there but children couldn't see many spiders. Teachers discussed the fact that many spiders are active at night and hide during the daytime. They also discussed the fact that some spiders build a new web each night and destroy it at dawn. Jenny Wagner's beautiful story, "Aranea," (Wagner, 1975) demonstrated the persistence that spiders show in rebuilding broken webs. Other pictures were found back in the classroom to show children spiders which "hid" more openly on webs, such a the leaf curling spider (*Phonognatha graeffei*) which pulls a leaf into its web, curls it up by winding silk around it, and has the perfect hiding place. The children looked for these clever little spiders on subsequent walks but were not able to spot one.

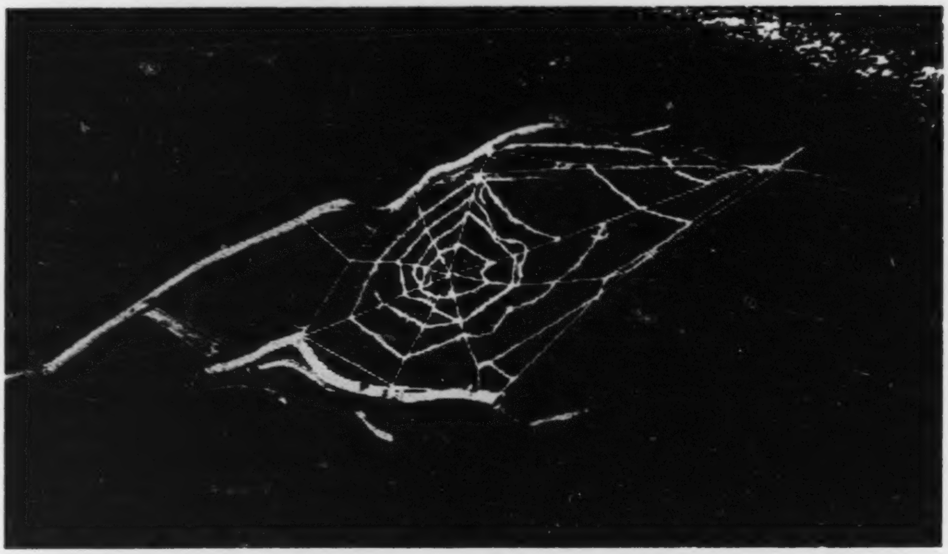
Luckily, a "dead" spider, which was actually a cast off skin, was found on one of the walks. Teachers were able to talk about the fact that spiders get too big for their skins as they grow. Spiders molt by crawling out of their old skin. Children were able to compare this spider skin with the cicada shells that had been brought in, and teachers could point out that the nymphs or larvae of insects also molt. Some pictures showing the process in both cicadas and spiders were found in books.

The walks were not solely to look for webs and spiders. Children were fascinated by a very large population of colorful Harlequin bugs (*Dinbymus versicolor*) in the area, which seemed to be constantly mating. This huge convent garden was also a place to explore and a place to play. A very old European Oak tree had branches that touched the ground and simply begged children to climb; an empty building was called "Cinderella's castle" by the children.

Weaving Webs

In the same small book that started the children's interest in games (Gould League, 1988), there were a series of diagrams on how a spider constructs an orb (traditional wheel) web. Andrew and Rachel, in particular, were very excited about these diagrams.

The next day a small group of children constructed a web from yarn using the book as a guide. The teacher helped them. Fluffy mohair yarn was used as the sticky silk, and regular yarn as the "dry" strands. Children added plastic spiders and paper spiders to the web, as well as some plastic insects and the cicada nymph shells. Later a tangle web was also made. This time it was made with string. It had the advantage that children were able to make it with minimum adult help, and it was much sturdier than the yarn web. This second web encouraged considerable "role playing" with the plastic spiders and insects. Web making was backed up by reading Jeannie Baker's wonderfully creative spider counting book, *One Hungry Spider* (Baker, 1982). Discussion followed about how she may have made her web and the collage animals for the book.



Use of Drawings

Drawing has always been an important way for young children to express their ideas. The beautiful and sophisticated drawings of the children of Reggio Emilia in Italy (Rankin, 1994) have shown the power of this teaching/learning tool.

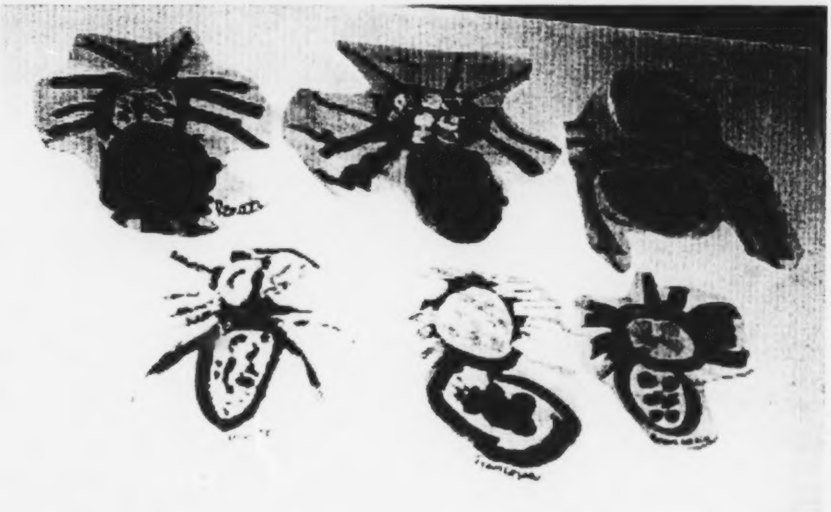
Children drew extensively throughout this project. One of the teachers' aims was for the children to develop an awareness of the correct body structure of a spider. Looking at the children's drawings was a way of assessing this understanding.

One early strategy was to ask the other adults at the center to draw a spider and then compare these drawings with some clear pictures and diagrams. The children were able to conclude that the grown ups had indeed "got it wrong" and not drawn a scientific picture of a spider at all. (They had, as had the children, drawn the legs attached to the abdomen or given the spider only one body part or two eyes, etc.)

These comparisons led to looking at the children's own drawings in the same way. The term "wrong" was avoided with the children's drawings; rather they were referred to as "creative" or "scientific" drawings. Another opportunity to discuss body structure was created when many children made edible spiders out of prunes, dried apricots, preserved cherries,

chocolate buttons, and thin strips of licorice. This was in preparation for making a thank you cake decorated with spiders for the museum curator.

Children found it very hard to draw the legs originating from the cephalothorax (the first body part which is a fused head and chest) rather than from the abdomen. About two weeks into the project, children were shown two large specimens of Huntsmen (dead) and encouraged to observe them and then draw or paint them. Only one child of the ten that chose to do this activity drew the legs in the correct position. Gradually, however, children did begin to draw scientific spiders as these drawings show.



While a focus on correct body structure was important, this did not mean that every drawing a child did of a spider was analyzed or discussed. It was felt that it was also important that children be largely free to express themselves in the way they wished. A few children never drew a scientifically correct spider; however, most did acquire a good understanding of body structure. (Two months after the end of the project 16 out of the 20 children were able to pick the correct drawing.)

Dance and Drama Sessions

The children were privileged to be able to have an hour each week with a specialist dance teacher. The dance teacher collaborated with the generalist staff in an attempt to integrate dance content in the development of the spider project. Movement stimuli such as spinning, opening and closing, creeping, rolling, and crawling offered the children the opportunity to experience and learn about the topic through their bodies. Small and large group dance dramas were developed by the teacher and children, with the children initiating content and creating scenes. There were wonderful whole group web weaving dances where a fine thread was used to connect the children and the teachers together in the space.

The children became very excited about the interpretations of spiders escaping from birds, spiders catching flies, and spiders "playing dead" with legs curled up. The content of the sessions was supported by a wide range of percussion instruments and vocalizations. The glockenspiel provided an appropriate stimulus for the weaving web dances.

Following each dance class, children were asked to reflect on and record some aspects of their dance experience through drawing. It was interesting to note that most drawings contained direct reference to the topic of spiders.

Constructions

Children were invited to use clay to make spiders early in the project. Several children made such models which went on display in the spider area. Later in a free choice construction time, one child suggested she could use the apple packing material and pipe cleaners to make spiders. The teacher took the opportunity to focus on body structure and encouraged the children to make scientific spiders by using two segments of the material, adding eight eyes and attaching the pipe cleaner legs to the first segment. She found a book with an appropriate clear diagram to which the children could refer.

During the second half of the project the class made a large paper mache spider. Teachers wanted the children to make a model of a "real" spider. Predictably, the majority of children voted to make a female Red-back spider. (The male is a dull brown). The basic technique of covering inflated balloons with strips of paste-soaked paper was used to make the two body parts. In keeping with the correct proportion of the particular species, the abdomen was made larger than the cephalothorax. Teachers helped children to get a sense of the true size of the species by showing them a pea which is the size of an adult Red-back's abdomen and reminding them about the specimen encased in plastic that the museum visitor had brought. Legs were made out of wire covered with masking tape.

Another construction activity chosen by some children was to make dioramas in shoe boxes. These featured spiders, webs and other objects, animals, or people drawn by the children. Pieces of yarn or string for webs were popular.

Phase III: Consolidating the Project - An Ending

When does a project come to an end? If it has been a satisfying project it doesn't suddenly finish. Children will continue to explore it in their own way even after teachers have formally brought the project to a close. (This group of children were still talking about a project on

Egypt they had done earlier in the year.) However as the term was ending, and all the aspects of the project web had been explored by some children at some level, it was decided by the teachers to draw the spider project to a conclusion.

The teachers' suggestion that a small party be planned to mark the end of the project was enthusiastically taken up. A meeting was held and the children put forward many ideas about what they would like to do at the "spider night," and who they would like to invite. Many suggestions were made. They wanted to invite their families, friends, the museum visitor and Cuddles the spider. They also wanted cakes, drinks, games, decorations, invitations, and a raffle.

A raffle was not something the teachers would have chosen for such an occasion, but it seemed to be very important to the children. The children appeared to have an understanding of what a raffle was. Andrew said "You have cards with different words and if you get a blank one you get a prize." "You have cards with numbers or a name and you win something" was the way Emma described it. So a decision was made to have a raffle.

Children enjoyed making the cards with the numbers and pictures on them. Prizes were in keeping with the occasion. All prizes related to the spider project or science. For example, plastic spiders, bug catchers, small electric motors, magnets and twelve-sided dice were prizes for the budding game makers. One grandparent even donated underwear decorated with Red-back spiders!

The result was a wonderful evening where the families were able to look at the children 's work, play all the games, and drink spiders (ice cream sodas). Cuddles, the Tarantula, returned from the museum to be the guest of honor. It was truly a celebration of the spirit of learning and a celebration of the accomplishments of the children. It allowed the teachers to thank the parents and the museum experts for their considerable contributions. This was an opportunity for parents to make spider pins with their children, play some of the spider games, read the children's stories, and read the documented interviews with the children at various stages of the project. The models, dioramas, children's paintings, drawings, board games, and quizzes were also on display as well as photos of the children throughout the project.

When children were interviewed after the spider night, an attempt was made to tap their feelings. They were asked if they enjoyed the occasion and which aspects they liked best. All children were very positive about the night. The food or drink were ranked as the things they most enjoyed. Sixteen out of nineteen children nominated one or the other . The raffle came in a close second, with fifteen children in the group having this on their list. Having Cuddles the Tarantula at the party was mentioned by eight children in response to this question. Making pins and doing quizzes with parents were also very popular.

Parents were also given the opportunity to comment, and they were very positive about the experience. They particularly seemed to value being able to look at their children's work. Attendance was high; only one family missed the night.

Positive Learning Results of the Spiders Project

Learning Outcomes

What did the children learn by participating in the project? Some of the easier things to measure are those in the area of knowledge and understanding. Less easy to measure are those gains made in the area of skills. Hardest to measure, but most important to achieve, are those gains made in the area of attitudes and dispositions. The interviews with the children gave some valuable insights into children's level of knowledge about spiders.

Many small group activities as well as class discussions were recorded on audio or video tape and these also yielded valuable insights into the children's understanding. In addition, "evidence" came from the children's drawings, games, dances, and stories.

Knowledge and Understanding

The indications from the interviews will be outlined here. These were very positive. Children were interviewed:

- In the early stages of the project.
- In the later stages of the project.
- After the expert's visit.
- After the Spider Night.
- Two months after the end of the project.

In the second interview of the project children knew more about spiders than in the first interview and they seemed confident about their knowledge. Here is an example of a conversation with one child early in the interviewing process:

Teacher: "What is a spider?"
Rae: "It's an insect."
Teacher: "What does it look like?"
Rae: "It looks like a very big insect."
Teacher: "How many legs does a spider have?"
Rae: "Six."
Teacher: "What's a web?"
Rae: "A thing that catches flies."
Teacher: "What's it made of?"
Rae: "Lots of stuff, thick gooey stuff."
Teacher: "Are spiders dangerous?"
Rae: "Some are." Red-backs and the ones that eat ants."

By contrast, here is an interview with the same child five weeks later:

Teacher: "Tell me the things you know or have learnt about spiders."
Rae: "They make their webs in different spots, the web is made of silk."
Teacher: "What does a spider look like?"
Rae: "It has eight legs and eight eyes."

In the second interview children expressed many accurate scientific concepts in their own words. Some children, such as Andrew, were very involved in the project and highly articulate, for instance:

Teacher: "Tell me things you know about webs."
Andrew: "It's made of silk. There are different types of webs. Sheet web Tangle web. Orb web."
Teacher: "Tell me about spiders."
Andrew: "A spider is a spider. Some spend their time underground, and some spend their time in the web."
Teacher: "What does a spider look like.?"
Andrew: "We all know that. Well its got a eight legs, a big fat body, eight eyes, the knife and fork (the palps) at the back spinnerets where they spin silk."
Teacher: 'How do spiders make their webs?'

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Others expressed ideas in a more original way:

Jenny: "They eat their food and then silk comes out from their bottoms."

Teacher: "What do spiders look like?"

Sarah: "They have 8 legs, 8 eyes. It looks like a number 8" (description of the two body parts.)

However, not all children were equally interested in scientific achievements. When asked about what things she had learned from the spider project, Sarah's first answer was, "Lots of things. Spider webs, spider cakes, spider cookies, spider milkshakes."

The appropriate knowledge about spiders that the children had acquired seemed to persist as shown by interviews conducted two months later. At this stage, the class was busy preparing for summer vacation and the festive season, which coincide in the southern hemisphere; so time permitted just a brief interview with each child. Teachers wanted to look at a few scientific ideas about spiders and see what the children's understanding of these were at this point in time. The children were shown six drawings of small invertebrates—including three that were obviously intended to be spiders—and asked to choose the best scientific drawing of a spider.

Children were also asked the names of some types of spiders, where spiders lived, what spiders ate, how spiders caught their food, and what spiders' predators were. The results were very encouraging. In terms of body structure, sixteen of the twenty children chose the correct drawing (#5). Children also gave appropriate answers to the questions, such as:

Teacher: "What are the names of some types of spiders?"

Hal: "Black and yellow spiders, Daddy long legs, Red-backs, Cuddles, Tarantulas, Huntsmen, trap doors, web casting spiders."

Teacher: "Where do spiders live?"

Hal: "Under the ground, in webs, in houses, in bushes, in a doormat or under a doormat, in dark corners or under a rug."

Teacher: "What do spiders eat?"

Hal: "Flies, small bugs, other spiders."

Teacher: "How do spiders catch their food?"

Hal: "Web casting. Some sit in the web and jump. Some jump for their prey."

Teacher: "What eats spiders? What are the spider's predators?"

Hal: "Bird, snake, marsupial mouse and sphink (skink)."

Hal's last reply showed a good memory of the game he had created based on the very first game that the children had played. Even children who had seemed less involved in the overall project had a reasonable understanding.

Skills

In terms of the skills that teachers had hoped would be addressed, there was reason also to be very positive. The children's more accurate recording of spiders and webs as the project progressed, indicated that their observation skills had improved.

Children's general research and investigative skills likewise were positively demonstrated. To help children, teachers and parents alike modeled a range of appropriate scientific processes. Children had used all of these processes. They had an opportunity to investigate real spiders and webs, use books as a resource, and talk to experts.

In terms of communicating their ideas and questions, dozens of opportunities occurred during the project for each child to express their scientific ideas. The student's contribution was always treated with respect.

Attitudes and Dispositions

The sphere of attitudes and dispositions is much more elusive to document. To really see if they had been successful in this area, teachers would have to look at children's behavior in the future. However many encouraging indicators occurred throughout the project. The children's understanding had definitely increased. Knowledge is empowering. It helps children increase their level of confidence and their level of positive feelings about science learning.

Another indication of the children's positive attitudes was the level of participation in all aspects of the project. With most activities, children had a choice whether or not to participate. Children clearly showed that they chose to be involved, that they chose to learn.

The amount of material that the children contributed from home also was an indication of how they felt about the project. If the children had not been truly motivated, they would not have sought out these materials or the parental help needed to do so.

Parent feedback was also valuable. Parents dropped in to tell the teachers about their children's enthusiasm for a web hunt at home, a spider book they had read together, or a relevant conversation they had with their child.

Conclusion

The authors are confident that the project approach is appropriate and powerful for science and mathematics learning with young children. Learning in other content areas was integral in the development of the project as well. In the spider project, children and teachers grew in terms of their knowledge, skills, and attitudes. As one parent wrote in response to Spider Night:

> What a fantastic project and a fantastic night! What lucky kids. This seems to be the ultimate—creative, fun, imaginative, informative and a lovely sense of caring and friendship. Thank you all!

One of the greatest outcomes of the project was that Angela truly did overcome her fear of spiders, and the children knew it. They also knew that they helped her not only to triumph over this fear, but also to become quite knowledgeable about spiders!

About the Authors

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Angela Barr is a Kindergarten teacher from Bentleigh, Victoria, Australia. Her interests include educating Early Childhood professional in learning how to incorporate children and their families in the process of Program Planning, Program Participation, and Program Evaluation.

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Chapter 17

Shoes Project

Carolyn A. Eckerty with Jeanette Allison

This chapter describes a four-week project on "Shoes." The shoes project was implemented over several weeks in a public school kindergarten, located in a small, midwestern rural community. The kindergarten program includes separate morning and afternoon sessions. When projects are offered, the same or different projects are coordinated between the two sessions. Project work remains one of many learning opportunities for children.

The shoes project has been part of my—Carolyn's—curriculum for over six years, although the focus of the project changes each year due to the differences in children's interests and background. Projects are included as a part of a larger kindergarten curriculum that is based on my goals and basic district objectives. Therefore, children have many choices for learning opportunities even while we work on a project. Project work continues to be a favorite choice of children because they gain so much from the investigation that projects offer. Also, related activities, such as clopping around in big shoes, are enjoyable for them because of the "buzz" of activity, a feeling of power, and a sense of pretending that they experience.

I have not always included projects in my program, however. Allow me first to explain how projects became a significant part of my program, then we will describe the shoes projects.

The Transformation to Projects

At one point I would have described myself as a traditionalist—even a *skeptic* of child-focused teaching approaches. I used to believe that children learned best from direct instruction. A typical kindergarten day included mostly workbook instruction. My interactions with children could be characterized as limited, because they mainly answered teacher-directed questions. Children's interactions with each other could be described as simplistic, attending to short-term interests such as television programs they had seen. They were driven by what they thought I wanted from them, and by what the worksheets limited them to. They weren't focused on deeper meanings of concepts, issues, or events, nor anything about which they wanted to explore.

Once a Skeptic, Not Always a Skeptic

After teaching traditionally for years, and seeing the limitations of this approach on children's thinking, I began to question its merits as the only way for children to learn. Then I heard about the project approach. It wasn't until I joined a project work interest group with Lilian Katz, from the University of Illinois, that I began to really examine my beliefs about early learning (see Katz & Chard, 1989). I have since described implementation of projects in my program (see Hartman & Eckerty, 1995).

Lilian and a group of graduate students, including Jeanette Allison, met regularly with a group of eight primary teachers for three months. Two of the teachers were already involved in project work. The other six teachers never had included projects before in their programs. Each teacher would share concerns about project work, questions about implementing projects, and feedback to help develop projects. It was a very supportive effort.

My First Project

Back at my school, another kindergarten teacher, Cindy Combs, and I decided to develop our first project together, "Our School", but we each still implemented the project in our own

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classrooms because our schedules were different. We did, however, collaborate on certain events, ideas, problems, resources, and results such as our classes sharing each project with the other class.

One year we videotaped the progress of the project before it was completed, and showed the video tapes to students as we were working on the project. Showing the videotapes helped students generate more ideas than they would have on their own. Ever since then, projects have been a continuous offering in my classroom. That was 15 years ago. I guess even a skeptic can change her views! Next, I share the shoes project.

The Shoes Project

In describing this project, I focus especially on the dialogue and decisions between children and me. I think it is important to include these details when trying to communicate with others about an ongoing teaching approach, like project work. Without these important details, teachers are less likely to understand the rich learning opportunities that constructivist approaches, like projects, add to a program. I begin with the reason, or rationale, for the shoes project. This is followed by the three main phases of the shoes project.

Rationale

Shoes are very important to kindergarten students, representing going out to play, being able to run fast, or enhancing role play. Children are also interested in how shoes work, such as fastening. Velcro is almost magical, it makes a noise when fastening or unfastening; two strips of cloth are sticking together without any glue, and it's so easy to fasten. Buckles present another challenge. And trying to tie shoestrings is the ultimate task for a kindergarten child. Being able to tie shoes strengthens the feeling of positive self confidence. For a five- or six-year-old, being able to dress without help, including fastening one's own shoes, also contributes to autonomy and self control.

Beyond the initial appeal, children gain more appreciation for shoes when they explore them in depth. I gain a deeper satisfaction about their learning process and the strategies they actually use to investigate (e.g., contributing their ideas, exploring information from many angles, posing questions, answering their questions, and so forth). What a difference in the quality of learning compared to my original days of teaching traditionally!

Phase One: Getting Started

I think of this stage as "gearing up." There is much to think about before children are involved in the heart of the project. For example, they need to decide: a topic, subtopics, what they know, what they want to know, how they will find answers to their questions, what will be their resources (human and material), how they will demonstrate their knowledge, and how they will use their project knowledge with everyday information learned at home and school. This phase includes a lot of discussions, planning, adjusting, and gathering information and resources. It's a very busy phase! Yet, much learning results from gearing up.

At the beginning of every school year, the children and I generate a list of possible projects that we would like to do during the year. The projects that are chosen to be completed during the school year depend on the interests of the children. In the fall of this past school year, the children were learning about the school and the surrounding area. The *shoes* project seemed to fit into the spring of that year. In the past, I have implemented the shoes project in the fall if children demonstrated an interest.

Some years this project starts with the nursery rhyme, "Old Woman Who Lived in a Shoe." Earlier in the year nursery rhymes are presented for repetition, rhyme, and familiarity. The children always think that it is very funny that people could have lived in a shoe for pretend!

And our project takes off from there. Usually the children choose to construct a giant shoe with boxes. The shoe is large enough for them to climb into, use for role playing, and learn additional information as they develop its detail.

I always start a project with what children *know* about the topic, such as shoes. Even though I may implement the same project another year, the questions and concepts are always different because I start with what *children know and about what they wonder*. Beginning with what the children already know elicits responses, and it also generates many questions about what they want to know and learn (see Figure 17.1). Figure 17.1 is a project web on "Shoes" and a sampling of the many questions, concepts, and ideas children proposed as a result of this process. This web also contains additional concepts gleaned from other lists and discussions throughout the project.

Last spring, students started to wear tennis shoes instead of heavy shoes (e.g., dress shoes and sandals instead of heavy boots). Even "jellies" were starting to appear on the girls' feet. Daily conversations about rainy weather during the opening sequence of the day created more emphasis on the shoes that children were wearing. For instance, several girls participated in weddings, and had talked their mothers into allowing them to wear their special shoes to school; some shared the shoes while telling about the experience. Many casual conversations about shoes resulted from this particular event.

In April, during afternoon storytime, I was sitting in my rocking chair and my feet were really hurting. So I took off my shoes to rest my toes and relieve pain. Children noticed that my shoes were not much bigger than theirs! (I'm 4'11" and do not wear a large shoe size.) But, they noticed that the shoes were quite different. The result was our initial, focused conversation about shoes. Children started comparing shoes: Who had the largest shoes? Who had the smallest shoes? "Let's measure!", they all shouted.

With this initial discussion about shoes, and different sizes, I thought it might be a perfect time to start a project. It was the end of the day, and time was growing short. I told the class we would measure shoes soon. I solicited a few more of their comments to keep in mind for a discussion the next day.

The next day, we all gathered on the rug during storytime for our first major discussion about shoes. Storytime was selected as the main discussion time everyday to plan our project. To support children's ideas, I read some of the books about shoes. Then, I asked children what they knew about shoes. Next, I solicited questions and wonderments about shoes. I listed all this information on chart paper. Below are examples of these lists. I like to begin lists with questions, or statements, to help children begin their inquiry (see Figure 17.2).

This day, we all had on many types of shoes. Before going home, I asked children to look at the different types of shoes around them at home and at daycare. I suggested they look in the closets and count the shoes they saw. Questions to consider included: How many closets? How many pairs of shoes in the closets? Who had the most shoes? The next day during storytime, several children reported that Mom had a lot of shoes, but Dad didn't!

Also, during this time, one of our weekly news periodicals was about sea animals. When discussing the octopus, one boy remarked, "I bet the octopus has a lot of shoes." For a moment the class was involved in discussions about what type of shoes the various sea creatures might wear. Some children thought about the animals as if they were cartoon characters that would wear anything. Others noted that these animals did not need shoes.

After discussing shoe types and differences, children talked about what they had learned as I wrote their responses on more chart paper. Then, I encouraged them to ask *questions* about which they wanted to inquire. These also were written on a large questions-sheet, as shown in Figure 17.3.

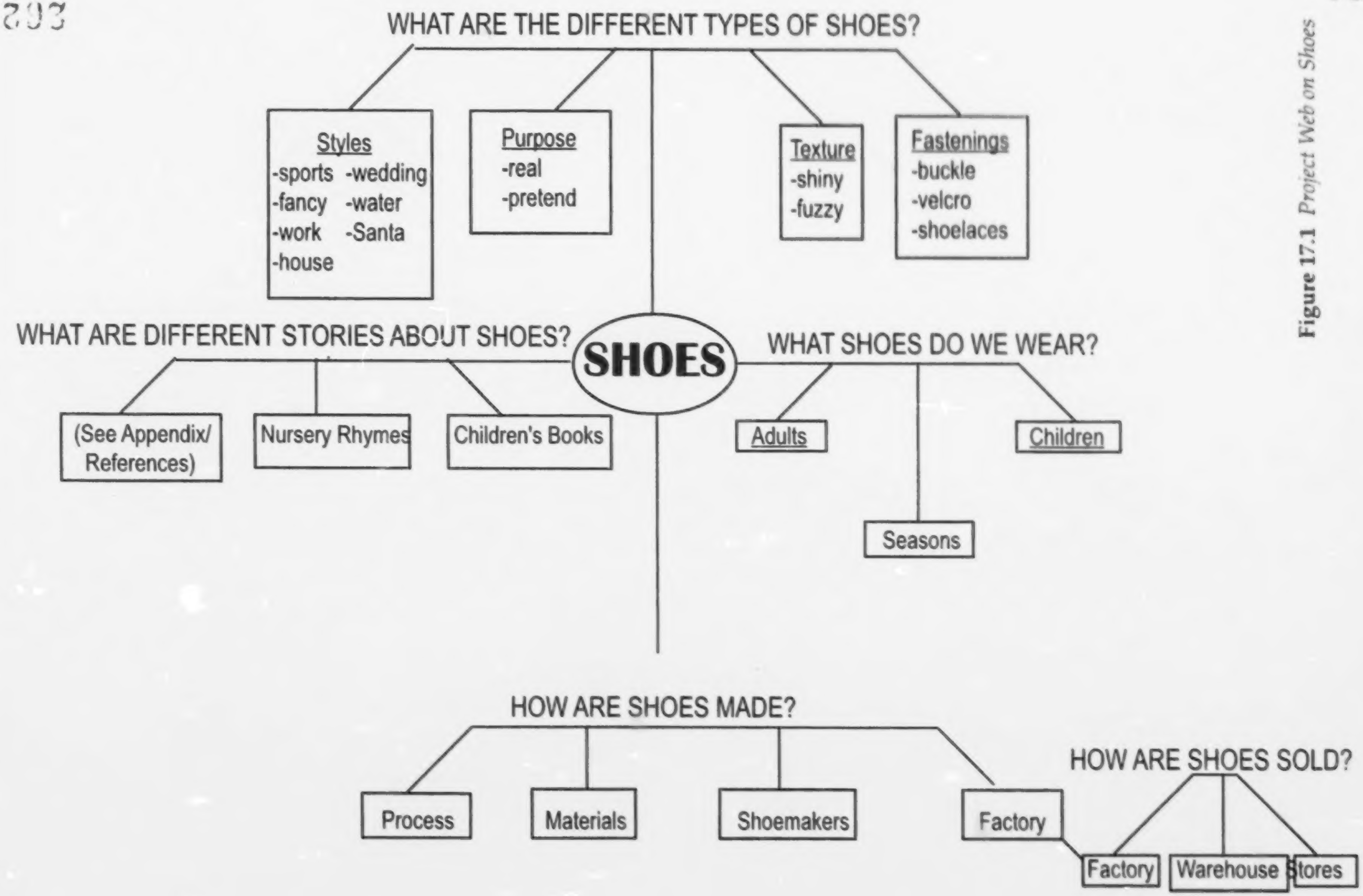
WHAT ARE THE DIFFERENT TYPES OF SHOES?
Styles
-sports -wedding
-fancy -water
-work -Santa
-house
Purpose
-real
-pretend
Texture
-shiny
-fuzzy
Fastenings
-buckle
-velcro
-shoelaces
WHAT ARE DIFFERENT STORIES ABOUT SHOES?
(See Appendix/ References)
Nursery Rhymes
Children's Books
SHOES
WHAT SHOES DO WE WEAR?
Adults
Children
Seasons
HOW ARE SHOES MADE?
Process
Materials
Shoemakers
Factory
HOW ARE SHOES SOLD?
Factory
Warehouse
Stores

Figure 17.1 *Project Web on Shoes*

WHAT WE KNOW ABOUT SHOES

Shoes make your feet get warm.
You can tie them, run, hop, and go anywhere.
You wear them on your feet.
You can play in the sand.
There are different kinds.
You can buckle shoes.
You can go anywhere (water shoes) in shoes.
You can play in shoes.
There are hiking shoes for hiking.
They are made out of thread.
You can walk around outside and not hurt your feet.
You can go walking in them.
We can run real fast in shoes.
We can walk in grass, make footprints from the shoes.
Shoes help you to not get your feet dirty.
You can tie them.
You can put sand in them!

WHAT ARE THE DIFFERENT TYPES OF SHOES?

Water shoes, sandals, walking shoes, cowboy boots, hiking boots, jumping shoes, rocking shoes, jogging shoes, slippers, back slip shoes, sneakers, moon shoes, ballerina shoes, captain planet shoes, rain boots, running shoes, tennis shoes, snow boots, high heels, Santa's boots, slip-on shoes, house shoes, etc.

Figure 17.2 *What Children Know About Shoes*

Some of the boys were very interested in special tennis shoes. Their favorites had cartoon figures or sports symbols of various teams. And, there were brands that seemed to be more special than others. The girls noticed shoes with special colors and special cartoon or movie characters.

I posted all of our lists on a Project Bulletin Board, so we could refer to them when planning our project. Also posted were photographs and posters related to shoes. The questions would be answered during activities, during research (e.g., by reading books, interviewing specialists), and by conjecture. For the questions we couldn't answer, we made educated guesses. We also consulted a project web that we created together (see Figure 17.1 again).

Phase Two: The Heart of the Project

By now, children seemed to be interested in learning more about shoes. Therefore, I adjusted the curriculum to incorporate the study of shoes. Different centers in the room related to

WHAT WE WONDER ABOUT SHOES

How are shoes made?
Why do women wear high heels?
Do shoes come in all colors?
How many kinds of shoes are there?
How many pairs of shoes did I (their teacher) have?
How do the people at the shoe factory know what sizes to make?
Where do the stores get shoes?
Can shoes be fixed?
Why did the "Old Lady Who Lived in a Shoe," live in a shoe?
How are shoes cleaned? And, can they all be put into the washing machine?
Are there different shoes for different disabilities?
Why do shoes have names similar to body parts?
    (e.g., eyes, soles, tongues, toes, and heels)

Figure 17.3 *What Students Want to Know About Shoes*

various project activities (e.g., shoe construction, shoe bouncing, shoelace construction). I am fortunate to have this type of flexibility. Even though teachers in our district use teachers' manuals for reading and mathematics, we are not locked into workbook pages. The manuals are one of many resources we consult for curriculum planning. Consequently, children can learn particular concepts using a variety of approaches, such as project work, centers, activity sequences, and individual work. I have discovered that our district objectives are met quite easily through these more open-ended approaches, project work included.

Next I share a decision process I go through about this point in project development, when I must consider both my goals and district objectives. Even though I have become more child-focused in my teaching, I continue to include some elements of the traditional curriculum I believe children need to know before moving on to first grade, such as handwriting and social skills. I also must consult district objectives.

Compared to those early years of traditional teaching, my starting point now is with children's interests and a more child-centered approach rather than adult ideals. I say to myself, "This is what I want to do (say, a shoe project for instance). How does it match, or fit in, with the scope-and-sequence of the district curriculum?" For example, if the scope-and-sequence for one week is the Letter B, I would consider that, but not isolate out the letter B, nor be bound by pre-fabricated materials, to dictate everything we do. Instead, I would have children do natural, real writing, and then remember to have children pay closer attention to the letter B in their writings.

I also preserve some aspects of centers and group activities that are in place before each project starts. Take the listening corner, for instance. One day during the shoes project, a record needed to be changed in the listening center. The children had not listened to *Elves and the Shoemaker* before, so I placed the record and book in the center. Seeing these, students wanted to find out what these items contained. After listening to the story and reading the book, they wanted to know: Why does the shoemaker have to make those shoes? Why didn't he just buy them? Right before my eyes, the project began to take on its focus: shoe making and selling. Children became very interested in seeking answers to their shoe making and selling questions. They became further interested in finding out more about questions and concepts they posed at the beginning of the project.

To follow-up on their focus, I read stories about how shoes were made (see references). I also conducted various library searches for books and resources about shoes. The children were especially interested in *how shoes are made*. At this stage, I sent home to parents a letter explaining the purpose, objectives, and background of the project. A letter requesting the donation of old shoes also was sent. For a shoe parade, I also asked parents to allow us to borrow unique shoes (see the section "Related Centers and Activities".)

For the donated shoes, I designated a display center so that children could examine their contents. I arranged to have some shoes cut apart so children could see what was inside. Those shoes were cut in various ways: Across the middle, lengthwise, through the lighted part, across the toe, etc. Children were really fascinated about shoe construction by now. They were eager to construct their own. As they designed their own "shoes," children frequently consulted the contents of the cut-up shoes. Doing so enabled them to develop detailed understanding about shoes' contents and construction. And, of course, this entire process resulted in even *more* questions to be explored!

The shoes brought in by the children were of different *kinds and sizes*. Some of the boys bragged that they had the biggest shoes, and wanted to weigh and measure them. As this was anticipated, the scales, tape measure, and other measuring devices were set out for the mathematics lesson of the day. To explore the concept of *shoe composition*, one child noticed that his shoes were made of similar material as the ball he had brought to school. Also, one of the books I had read told about some new shoes being made of rubber. What followed was a discussion about shoe materials, and a big question: Would shoes bounce? Students wanted to test their hypotheses about shoes and bouncing.

To do this, children selected shoes made of rubber, and set up a place in the room to experiment with the dynamics of bouncing. I gave them permission to stand on a chair to add some height to their drop. Three children were chosen by the group to select shoes and three more were chosen to conduct the drop. Three kinds of shoes were used to test the dynamics of bouncing: two types of athletic shoes and one canvas shoe. The drop was done and the results recorded. All shoes did bounce a little, but the rubber ones bounced a little higher. At least that is what the children observed!

Then, they changed their focus more to shoe *construction*. They explored even more problems: How can we make shoes? They decided on simple construction procedures: Trace the foot on tagboard. Then with various materials, make all the parts of shoes adhere together. Wanting to test their shoe making skills, children exclaimed, "Let's try different ways to make the shoe stay on when we walk around!" They tested the strength of their shoes' constructions by walking in all different ways and on various surfaces.

This experiment led to another question about shoe construction: What about shoestrings? Can you use any material for shoestrings? Let's try different materials for shoestrings was the focus for another corner. Responding to their interests, I placed construction paper, paper punchers, pencils, and scissors in a shoe-construction center for children to trace their shoes, cut them out, and make shoestring holes. Different kinds of string, yarn, pipe cleaners, straws, and thread were used as shoestrings in the paper shoes. The children experimented with these materials in many ways. The constructions went through a process of trial-and-error until children figured out the better methods to build shoes with strings.

Naturally, then, velcro became a follow-up focus of shoe composition and construction. Several pairs of shoes with velcro strips were placed on a the shoe display table. After gathering as many small magnifying glasses as possible, the children had time to see what made the velcro stick together. A larger magnifying glass helped them see the plastic hoops and hooks. After a while, students had conducted much problem solving regarding shoe composition.

All the children made at least one pair of shoes, each being uniquely different. In our discussions, several children mentioned other items that can be purchased in shoe stores. They also wanted to "sell" their shoes. These shifts in interest changed the focus of the project.

Phase Three: Refining and Concluding the Project

By the fourth week, students had participated in many shoe-related centers and activities around the room. Consequently, students had constructed many products that reflected their knowledge about shoes. To bring their efforts together, I suggested that they consider making a big construction where they could use their products. I had in mind that a perfect experience would be to make a shoe store. But, I wanted children to come to this conclusion. I reminded them of their interest in selling shoes. Then, I posed these questions: "We have all these shoes and shoe products, right? But where do we get these? Where do you get your own shoes?" I guided the children through a reasoning process that went like this: We have shoes to wear, but they are made somewhere—a shoe factory. But how do the shoes get from the shoe factory to us—a shoe store.

The class then decided to make a shoe store for our project. This step in the project caused children to refine their focus. They became focused on sizing, purpose, materials, and design of shoes. I helped them decide on roles and responsibilities for this new step. I posted a sign-up sheet for the children to chose the role or responsibility in which they wanted to be involved. Some of the various roles or responsibilities of the shoe store were designing the store, building the store, painting the store, advertising, pricing and money, and miscellaneous duties. The last category includes making other merchandise (shoe buckles, socks, purses) and economics (pricing, cash registers, money, sales slips, credit cards).

The shoe *store* was made with large boxes and lots of tape. It was painted, and children used various items in the room as chairs and footstools for customers and sales personnel. When inquiring about sales personnel, our project integrated nicely with *social studies*. We connected the shoe project to social studies by asking, "What are different shoes people have to wear for their jobs?" A group of children elected to explore various jobs and the shoes these people would have to wear. We created the following list:

SHOES PEOPLE WEAR FOR THEIR JOBS

Secret agents—tennis shoes so other shoes won't get muddy and broken; black shoes so the shoes won't show up in the dark;

Mountain climbers—tennis shoes so they can climb better; hiking boots with spikes so they won't fall off the mountain;

Astronauts—plastic shoes because they wear plastic-looking suits; they fly better in plastic; or even leather boots so they can jump better on the moon; heavy boots so they can stay on the ground when there is no gravity;

Other personnel who need special shoes to do their jobs—Fire workers, postal workers, construction workers, ballerinas, and baseball players who needed special shoes to do their jobs.

Students continued to participate in the center designated for shoe construction. More shoes were created using egg cartons, boxes, tape, and other items. The real, cut-away shoes were consulted to see how shoes were put together. Paint and donated material and yarn completed the shoes. A few pairs of shoes were made big enough to be worn by the designer.

Other shoes were made for dolls, animals, and for other reasons. A few children assumed the roles of clerks, and others wanted to be the boss. A problem solving time was instituted to prevent warfare. Children negotiated a schedule so all could have a turn to be "boss."

Shoemaking tools were brought in so the children could see real tools used for repairs. Quite naturally, children became curious about the shoe repair business. A shoe repair shop was added on to the shoe store. By now, we had the following "businesses" associated with shoes, *shoe store, shoe factory, and shoe repair.*

Recall the boy I mentioned earlier who was interested in the octopus needing "lots of shoes." He decided to make a book with pictures of various animals and the shoes they might want to wear. When he was working on this, several other children became interested and started making their own books about animals that might wear shoes and what those shoes would look like.

Some children even invented silly rhymes about shoes and animals. Another child pointed at the shoes that were brought in, and said, "Look at the clogs—clogs are for the dogs!" Which led to "Look at the boots—boots are for roots!" "Look at the shoes—shoes are for twos!" and so on. Children were involved in the detail of shoe making, selling, and repairing for approximately another week. They participated in other related centers and activities as well (e.g., writing books about shoes, personnel, and businesses). Some of the most common centers and activities that occurred during the project are discussed next.

Related Project Centers and Activities

As you can imagine, a lot transpired during the project. Although constructions were the most popular facet of project work, many children participated in related centers and activities. The overall curriculum incorporated most content areas during the project as well. These content areas were integral in all our experiences.

Science concepts, for example, related to the project included *foot protection* and *shoes as pots for plants*. Mathematics concepts included concepts such as *counting, measuring, graphing, and area*. Other content areas related to the shoe project were, for example, social studies and visual arts with concepts such as *parades, games, and unusual art*. Below are examples of some concepts mentioned above.

Foot Protection

Most of the children knew the reasons we wore sandals in the summer and snow boots in the winter. But, I thought it would be engaging to really compare the differences at school. After obtaining the permission of the kitchen staff, we planned an experiment. The children selected several different shoes. We took the shoes, paper and pencils, and went to the cafeteria to experiment by putting our hands in the shoes and sticking the shoed hands into the freezer in the kitchen. We recorded that boots were the best for keeping feet warm. The next sunny day, the children planned to do the same experiment in the sun with boots and sandals. This was done during outside play time by the children who were interested in the outcome.

Shoes as Pots for Plants

In science, we already had been planting seeds and cuttings before the shoes projects emerged. It was becoming difficult to find containers for plants. Then, one student asked, "What are we going to do with the old dirty shoes?" Another child suggested using those *shoes as pots for leftover plants* and seeds. After a discussion about which shoes make the best "pots" for plants, we selected a few and proceeded with the planting. Some shoe pots leaked when watered, but others made really neat plant homes.

Counting

Many mathematics activities were based on the concept of *counting*. We were counting to 100 and counting by 5's. The children also heard me counting the shoes on display by 2's. Even when I made a mistake, they learned about counting shoes in multiples. Our next unit in mathematics was addition, so it was time to start adding shoes together and recording our results. Jon has two shoes and Cassie had two shoes. 2 + 2 = 4! We were beginning to write number stories.

Area

I also introduced the concept of *area* during the project. As we had extra shoe boxes of various sizes. I set out paper, pencils, and manipulatives to let the children experience the concept of area. First they placed the shoe box on paper and traced around it with pencils. Then the area inside the tracing was filled with manipulatives. Since different manipulatives were used, the children wrote their name on the paper, drew a picture of the manipulative and wrote the number of how many it took to fill the area inside the tracing of the box. (The lid would work as well as a tracing.) They then placed the paper with all the information inside the box. At free time, the children could go to the boxes to compare the differences in the sizes of shoe boxes and the different amounts of manipulatives.

Measurement

Measuring was another concept that children learned more about during the project. I asked the children which would be the longest: the distance around the length of the sole-heel to toes, the distance around the shoe ankle high to the top of the shoe, the distance from the heel of the sole to the top of the shoe, or the distance around the instep. With some string, scissors, and shoes for each group, we began the activity to find out. The children measured and then cut the string to indicate each length. The strings were then glued on paper. The string that measured the sole was placed on the bottom of the paper. The string that measured the distance from the heel of the sole to the top of the shoe was glued in that position on the paper, and so on until all the pieces of string were glued on. Each group then presented the results of their experiment.

Graphing

Graphing was yet another concept we covered throughout the project. At the beginning of the project, it was time to take down the graph showing the children's bedtime and put up another graph. Shoes seemed to be the subject of choice. On the third day of "shoes", the children colored in a space on the graph to indicate the shoes they had worn on this day. The graph had spaces for tennis shoes, boots, sandals, and dress shoes. One class had 16 tennis, 4 leather, and 3 boots. The afternoon class had worn 5 pairs of tennis shoes, 0 leather shoes, and 1 pair of boots.

Shoe Parade

By the middle of the project, we had finished the books that introduced project topics. We now were ready for new stories. Our reading series (Silver, Burdett, & Ginn) had a story titled *The Naughty Shoe*. The other kindergarten teacher, Cindy, and I decided to present that book next.

The Naughty Shoes is about the night the shoes in the town went walking on their own. The children thought that was really funny. So we decided to actually have a shoe parade. Part of our shoe parade involved switching pairs so that each child could wear two different shoes at the same time. There were some unusual shoe combinations! We paraded around our own room, and then went through the other kindergarten room. In return, Mrs. Coombes' class paraded through our room.

We also made a book of the shoes in the parade. Students drew the shoes they wore in the parade. It was difficult for them to decide on the categories for grouping the shoes in the book. The morning class focused ballet slippers, cowboy boots, Dad's work boots, etc. The afternoon class concentrated on athletic shoes.

Shoe Game

I had the children sit in a circle and take off their shoes. They put all the shoes in a big pile in the middle of the circle. One student was blindfolded and turned around and around. Then, the blindfolded child was pointed towards the pile of shoes and asked to find his/her own shoes. After about 10 seconds, the children on the outside of the circle gave directions to help the blindfolded student find the shoes. Soon thereafter, the blindfolded child took off the scarf, and was free to find the shoes. I continued the game until all the children had a chance to find their own shoes.

Unusual Art

Our regular art experiences were put on hold during the project. Instead, we inserted some *shoe art*. We made shoe rubbings with crayons, paper, and different shoes. The textures of the shoes made interesting designs that were displayed in the hallways. In my collection of pictures, I had a real car that was rebuilt to resemble a shoe. This led to students drawing pictures of what shoes might look like if they were houses, cars, or animals. Also we used old shoes for print making. Several different colors of tempera paint were poured into pie tins for this experience. Students used shoes to make designs, paths, tracks, and trails with the shoe prints. For these activities, I restricted the use of shoes to soles only.

Summary

After about four to five weeks, all the books about shoes had been read several times. Our homemade books were completed, the shoes started falling apart, and children shifted their interests to other events and ideas. The plants were growing, and nicer weather allowed for more outdoor play. Some shoes went home, while other parts of the project were disposed of as ecologically correctly as possible. We were finished with shoes and beginning another project.

Conclusion

When I first included projects in my program, I averaged about one or two each year. In more recent years, I have included four to five projects a year. The projects are not always on the same topics each year. Some years a group of children are more mature and ready for working in groups. Other years the children seem less mature, and they need more time for individual play at the beginning of the year. In that case, I postpone the project until a later date. Knowing how to tailor projects to each group has come from observing children's needs and interests.

As mentioned earlier, I did not begin my career in teaching as an early childhood educator. Rather, I began as a more traditional elementary teacher. The result was a focus on basic, predetermined skills acquisition rather than on meaningful learning opportunities. Feedback from parents was limited as well. They did not comment on the program or curriculum very much. Since adding project work, however, parents approach me more and comment on what their children are learning. Parents are much more directly involved throughout the school day also. They, for example, send in materials, books and information associated with projects. They also offer their own personal assistance, such as one parent who sent in wooden shoes from Holland, which was the origin of their family.

Changing my original, traditional ways to become more responsive to children has been a rewarding process. It did not happen over night, however. It continues to be a process I face daily, and is worth my time and effort. Reflecting back 15 years to the time I first joined the project work interest group (with Lilian Katz), I remember giving myself permission to take as much *time* as necessary to ensure that both children and I were comfortable with the transitions we were making. Since then, projects have been a very valuable part of our day.

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Puddles and Ponds: The Project Approach Applied to Aquatic Habitats

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The chapter describes a project that a teacher used with a resource available in most elementary classrooms: aquaria and simple aquatic systems. The project was implemented in a second grade classroom. We will illustrate the implementation process with specific examples of how children used water, plants, and animals in self-contained habitats as the focus of investigation and projects.

Whether working in rural, suburban or urban environments, teachers and children have easy access to a variety of materials, many of them recycled, which they can use to construct models of aquatic habitats. In the second grade classroom, these models became the focus of class, small group, and individual activities for investigating the components and interactions of nature and how people influence these systems. The project focused on several scientific and mathematical skills and included activities such as drawing, painting, model making, reading, writing, creating stories and poetry, problem-solving, and dramatic play.

Rationale for the Puddles and Ponds Project

It is our experience that there are many aquaria or other suitable supplies already in classrooms which are not being used to their best advantage, or if they are being used are viewed as an accessory decoration, primarily ignored in the course of curriculum design and instruction. The field experiences and classroom models described in this section made use of these available resources. The classroom aquarium materials can be purchased at large discount stores, pet shops, second hand stores, and (most inexpensively) at yard or garage sales. Many classrooms have an aquarium already set up in the children's play or quiet area. These can easily be used as the focus of the puddles and ponds project.

With teacher supervision aquatic habitats are easy to set up by young children and generate a tremendous amount of enthusiasm. Materials such as gravel, soil, and water are easy to handle and are of interest to children. The active engagement of children from the beginning of this project ensured their active involvement through a sense of ownership, and created a greater understanding of many scientific and mathematical concepts.

It is our experience that children from rural, suburban, and urban environments are familiar with this topic and can learn much about their environment through the puddles and ponds project. It seems a universal experience that children are magically drawn to puddles and wet places. Walks to and from school on rainy days often end with wet feet and clothes. The pet shop and the fish section at the department store attract many children's attention. The puddles and ponds project is particularly suited to early childhood education because it embodies many of the practices appropriate to the developmental level of the child.

The Learning Goals of the Puddles and Ponds Project

Four types of learning goals—knowledge, skills, dispositions, and feelings— were integral throughout this puddles-and-ponds project (Katz & Chard, 1989). The principles upon which children learn best in the four goal areas differ. Therefore, examples are provided under each goal. The focus of the project was also guided by the goals presented in *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993) which specifies how children should progress toward science literacy, and what they should know and be able to do by the time they reach a certain grade level.

To enhance *knowledge* acquisition in the puddles and ponds project, children were provided opportunities to actively engage in learning by asking questions, seeking answers, collecting information, counting, measuring, making observations, and discussing findings. The activities stimulated curiosity in children and assisted them in taking an interest in their environment and the workings of nature. The teacher facilitated the learning process by suggesting possible project topics judged worthy of children's study, integrating children's ideas into the project, and supporting the choices that children made about what tasks to undertake. The teacher acted as a consultant, and supervised and monitored the children's work (as suggested by the American Association for the Advancement of Science, 1993; Katz & Chard, 1989).

The acquisition of *skills* in the puddles and ponds project were strengthened through such processes as imitation, trial and error, instruction, observing carefully, describing things accurately, and using tools. An important part of skill development requires that children tell others about what they see, what they think, and what they wonder. Primary school children are more likely to acquire scientific and mathematical skills when they are meaningful to them during their day, in their home, and as they interact with others (American Association for the Advancement of Science, 1989; Katz & Chard, 1989).

Dispositions in children were strengthened when they were given opportunities to inquire, create hypotheses, question, and interact with their peers in groups as they explored the wonders of the puddles and ponds project, and developed their own aquatic habitats. Because of the value that science places on independent thought, the teacher helped to foster scientific dispositions by assuring children that even though they were part of a team, they were free to reach different conclusions from their peers.

Lastly, the puddles and ponds project was extremely suitable to the development of *feelings* in the children because several instructional approaches were employed. Children from diverse backgrounds, abilities, and developmental levels felt competent and adequate because of the variety and types of tasks that were presented to them. Feelings were further enhanced when children were given opportunities to interact, cooperate, and coordinate their efforts within groups of children. The puddles and ponds project provided opportunities for children to engage in meaningful work where they could feel a sense of competence and contribute to group effort.

Phases and Processes

Next, we describe three main phases of this project. We also explain the learning processes students encountered as they participated in the project (see Allison, this section). Throughout the phases and processes, all four learning goals were addressed (i.e., knowledge, skills, dispositions, and feelings).

Phase One: Assessing Children's Knowledge and Experiences

In preparation for the puddles and ponds project, the teacher anticipated experiences that children had with water and aquatic habitats. Some of the children had explored ponds with their parents or had an aquarium at home. As children shared their stories, other children became more interested and began to ask simple questions such as, "What did you find in the pond?" or "What lives in your aquarium?" These questions provided a basis upon which to develop additional opportunities for the children to find answers to their questions.

A research area was available in the classroom which contained books, posters, magazines, dictionaries, children's encyclopedias, and writing materials. A class chart or individual charts of "What I know," "What I want to know," and "How I will find out" were also posted in the research corner and continually updated. Books that the teacher and children found helpful are provided in the reference section of this chapter.

Correct understandings, missing ideas, and children's misconceptions were first identified. Several research studies (Brody, 1994; Munson, 1994; Osborne & Cosgrove, 1983; Rafel & Mans, 1987) have been completed in this area; however, the specific knowledge that a classroom of children has is integral for teacher planning and direction of the project. Another important aspect of assessment is the identification of children with similar interests, knowledge, or concerns. In this project children were often times grouped together to research topics of similar interest such as finding information, exploring outside pools or building aquatic habitats.

Previous Studies of Student Understanding of Water

To help prepare for the project, the teacher spent time finding out about children's understanding of water. For example, in a study (Osborne & Cosgrove; 1983) of the phases of water (solid, liquid, gas) children were asked a number of questions about evaporation and condensation such as, "What happens to a wet dish left on the counter top?" Children also observed a jug of water first heating and then boiling. In their oral description of the phenomena, few children gave correct explanations of what was happening. In the case of the concept of dissolving of substances in water (or solutions) children exhibited little understanding of how substances dissolve in water.

According to Osborne and Freyberg (1985) young children's problems in understanding and explaining phenomena related to water, appear to be associated with unobservable events. Other conclusions drawn from these studies offer explanations of these misunderstandings. These include: children's sensory data leads to naive conclusions (things disappear or go away when water evaporates into "air"); school instruction does not seem to influence children's understanding; and sometimes classroom instruction influences children's understanding in unanticipated ways (sometimes leading to more elaborate misconceptions).

The research on children's understanding of water can be summarized as follows: Children hold onto their views of common phenomena that they have acquired through personal experience and as they progress through school; water-related concepts are presented in abstract ways and do not relate to the everyday experience of children.

The puddles and ponds project helped change this situation by engaging children in meaningful concrete activities which were based on their interests and questions. Through the construction of classroom habitats and observations of water in nature, children were able to observe first hand the phenomena described above through direct experience with water. The puddles and ponds project provided contextual experiences which allowed the children to investigate the answers to questions in meaningful ways. The approach aided in correcting misconceptions described in these studies.

In addition to class discussion and research by the children, the teacher created a curriculum web (Katz & Chard, 1993; Workman & Anziano, 1993) with the children's input in order to develop additional ideas about the project's scope and directions to follow. The curriculum web provided insight into the children's understanding and interests (see Figure 18.1).

Organizing all of the information generated in the assessment phase can be difficult. For example, how can the children's ideas be collected, organized and shared with everyone?

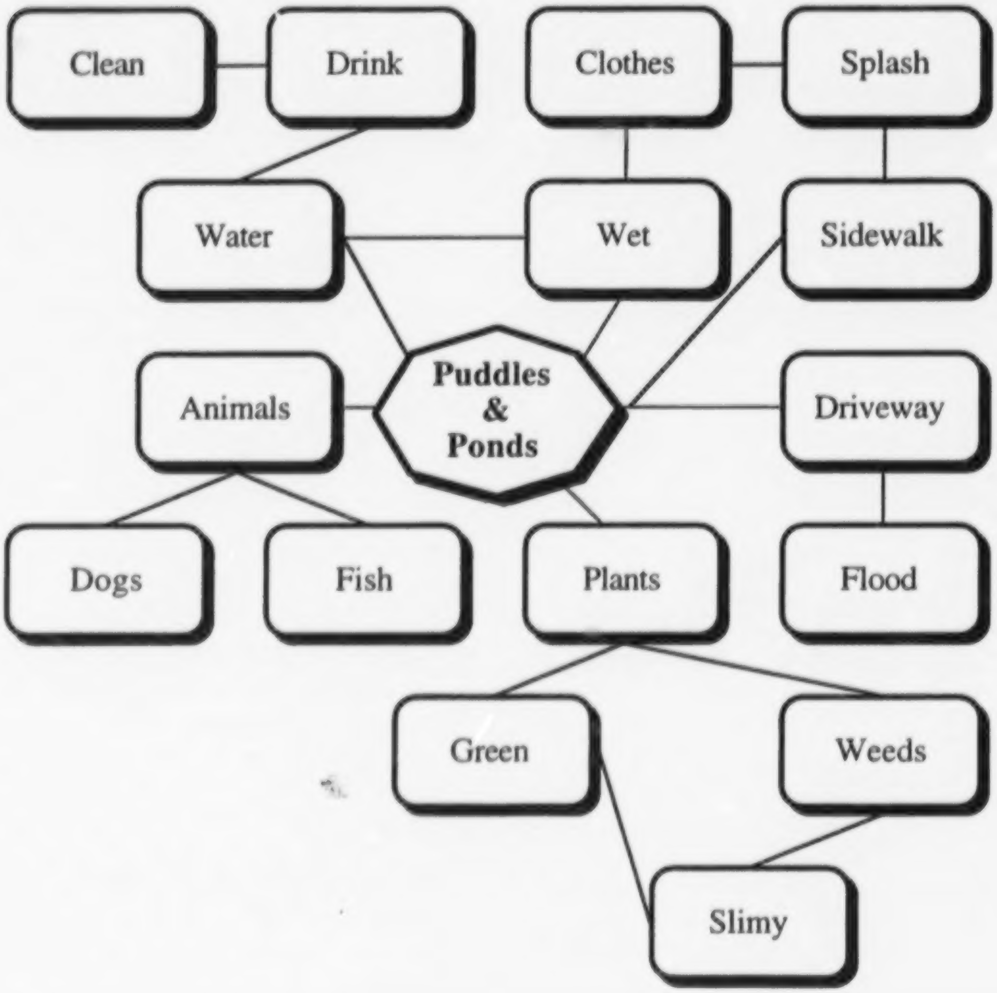
Clean
Drink
Clothes
Splash
Water
Wet
Sidewalk
Puddles & Ponds
Animals
Driveway
Dogs
Fish
Plants
Flood
Green
Weeds
Slimy

Figure 18.1 *Curriculum Web*

The activity that follows was a helpful summarizing process and assisted in grouping children based on their experiences and interests.

Activity: Puddles and Pools of Children's Understanding

Have you ever wanted to be able to read other peoples' minds? This activity allowed the children to share their thoughts about common interests. Class discussion led to identification of experiences, concerns, and knowledge related to water, puddles, ponds, and aquatic habitats. In this activity, children learned to categorize ideas about puddles and pond; identify relationships among interests, concerns, and experiences; and understand that their peers could be an important source of information. The activity provided the children with a strategy to record their knowledge and relate new concepts to information they already knew. It built upon the children's interest in talking with their peers about experiences and opinions, and encouraged them to share knowledge and concerns. Children used the diagrams they developed to identify further interests and conduct research.

Through the use of puddles and ponds of ideas, the teacher was provided with a record of the children's experiences, concerns, and understandings relating to water. Assessing children's knowledge or preconceptions was one of the most important strategies for effective teaching. Children's preconceptions may be accurate and facilitate learning. Other times they may be misconceptions and can impede learning. In either case, prior knowledge is considered robust and has an influence on new learning (Novak & Gowin, 1984). Children's prior knowledge related to water was used to plan activities and to make concepts more relevant.

Materials needed for the activity included: index cards or pieces of paper, markers, and masking tape. The following steps and activities were performed by the teacher and the children:

- The teacher began by introducing a story related to water, puddles, ponds, and aquatic habitat. The teacher asked if any other children had similar experiences, and shared with the class that they would be conducting an activity to help them learn which children had similar interests and concerns regarding puddles and ponds.
- Each child wrote, drew, or dictated a memory on a piece of paper. The children were asked to share the memory. From this discussion, similar experiences were noted by the teacher. The related papers were collected and taped in a group on the wall. Groups or memory pools continued to form until all the memory cards were posted. The teacher drew a circle around each memory pool (e.g., swimming, fishing) and labeled it. Children discussed common interests and how they were formed.
- On another day the children wrote, drew, or dictated a fact they know about puddles and ponds. These were collected and sorted in related groups around the memory pools.
- On the third day the children wrote, drew, or dictated questions they had about puddles and ponds. Again, these questions were collected and related to the existing idea pool. For example, a line was placed between a memory of going to a puddle or pond and a question about the animal who lived there. The children discussed the network of pools created with their memories, facts, and questions and described the links between the pools .

Children made their own ongoing idea pool network and kept track of what they were learning about water. The teacher had the class refer to these diagrams occasionally to assess children's understanding of concepts. Referring to their idea pools, children wrote their experiences, concerns, and knowledge in the format of a short story or in a journal. If they had unanswered questions, they were encouraged to research the answers.

Phase Two: Finding Out About Puddles and Ponds and How to Construct Aquatic Habitats

In the second phase, the children continued in their exploration of the puddles and ponds project. At this point in the project children began to ask more and varied questions, such as these examples: "What kind of animals live in pools and ponds?" "Where can we find pools and ponds?" "How do you build an aquarium?" "What can we put in the aquarium?" Where can we get fish?" "What do the fish need to eat?"

The children first found out more about puddles in their immediate area. All of the children in the class indicated that they had played in a puddle. However, most children were entirely unaware of puddles (temporary or vernal pools) as a valuable and vulnerable aquatic ecosystem. Many people regard puddles or standing water as a nuisance and avoid them so their shoes don't get wet. The following activities were planned to help the children find answers to their first two questions.

Activity: Investigating Puddles in the Neighborhood

Puddles that form near schools and in the neighborhood provided excellent sites for investigations relating physical and life science. Puddles may form at any time of the year; however, those that form during the spring season may last longer and provide more interesting studies. In the spring, temporary pools are associated with warming temperatures, greater available light, and exemplify the burst of new life associated with the season. Determine for your climate what time of year that puddles and pools are likely to form. In temperate North America, temporary pools often form in late winter and early spring due to runoff from snow and rain.

Puddles that appear after a rain and last for several days or weeks can be a wonderful teaching resource. A whole world of life can appear in such a pool, with a fast-paced lifestyle geared to win the race against time; that is, the time when the pool dries up. This lifestyle has a major benefit, the absence of predators like fish that abound in more permanent water bodies. The major risk is that the pool might dry up and disappear before plant and animal life cycles can occur.

Children learned to locate, observe, and monitor temporary pools in their local environment and recorded observations about physical and biological aspects of the pool during its existence. In addition, children were given the opportunity to recreate a temporary pool in the classroom which helped them to understand and appreciate the importance of temporary pools in the larger ecosystems.

Materials needed for the activities included a thermometer, hand dip net, magnifying glass, ruler, string, field guides, water quality measurement kits, and classroom aquaria.

Locating the Pools

Children were taken in small groups by parent volunteers on repeated occasions to explore the out-of-doors which included the immediate yard, the outlying fields, and nearby parks. Pools were located and the children began to make observations of the puddles and pools. They constructed a neighborhood map and marked the location of significant pools. They gave each pool a number and made decisions regarding who would observe them during their entire existence.

They initially discovered that the daily, seasonal, or annual variation in precipitation in any given area can affect the size of puddles and pools as well as the time they are in existence. The overall volume of the pools affects their carrying capacity (the numbers of plants and animals the pools can safely accommodate). There can be significant differences in pools from year to year.

Monitoring the Pools

With the continued help of parents, the children used data sheets to make observations of their pool every other day during the pool's entire existence (Monday, Wednesday, and Friday) and noted changes. Some used sidewalk chalk to outline the edge of the puddle and were able to answer their question, "Does it change?" Some of the children used simple equipment such as a thermometer, ruler, string, hand dip net, and magnifying glass to help them monitor the pool.

The variables that children decided to monitor included: (a) water temperature, which was easy to measure and had a significant effect on the metabolism of pool animals; (b) estimating the depth of puddles, which affected the carrying capacity; (c) animal and plant types, which could be determined with the use of field guides; (d) numbers of animals, which could be determined with a hand dip net; and (e) number of plant types. They were also on the lookout for signs of other animals (such as animals tracks) and did note that other animals (such as a dog) drank there. Children recorded their findings on a data sheet. The findings from the children varied considerably and this provided an opportunity for them to share their outcomes, question one another, and compare and contrast results.

Classroom Temporary Pool

Because the children had developed such an interest in locating and monitoring the pools outside their classroom, the teacher decided to continue with the interest by creating a pool in the classroom that would be readily accessible for observation. On a field trip walking in the rain to visit areas where potential temporary pools formed, the children and the teacher took samples of soil from sites that looked like they had the potential to become significant puddles. These appeared first as simply muddy areas which don't tend to dry out. The soil was placed in a plastic container and carried back to the classroom where it was filled with water.

As the children monitored their neighborhood pools, some of them compared the animal and plant life in the pool to the organisms which grew in the classroom pool with hand held magnifying glasses and microscopes. They were encouraged to note the similarities and differences between the two types of pools and charted some of their findings. For example, they noted that the classroom pools were more stable and the level of water did not vary as much.

This led to discussions of evaporation and the role of the sun in promoting faster evaporation of the water. Because there was more fluctuation in the level and temperature of water, organisms in the outdoor pools appeared and disappeared at a faster rate compared to the classroom pool.

Pond in a Bottle

Now that the children had some experience observing pools outside and inside the classroom and recording information, the teacher decided to share a personal interest with them. The teacher noted that since we are all surrounded and are each an integral part of our ecosystem, it is important that we understand the components and relationships of the natural world which surrounds us. Disturbances to our ecosystem offset the balance of our natural ecology, human health, and well being. The following was a helpful and fun activity in which children constructed their own ecosystem and modified it according to their individual interests.

The basic ecological principles upon which this investigation was based were: (a) everything is interconnected and intermingled with everything else and we are all in this together, (b) people need to discover which connections are the strongest and the most important to us and other species, and (c) we can learn a lot about nature, but nature is so incredibly complex and dynamic that such knowledge will always be quite limited.

Materials needed for this project included: 2 liter plastic bottles, gravel, sand, pond water, snails, small piece of cloth and rubber band, soil, seeds, and water.

Children were given guidance and instructions in building their own bottle ecosystem:

1. Obtain liter pop bottles and remove the labels from each (reuse bottles from student families).
2. Cut each of the bottles in half.
3. In the bottom half of one bottle place clean gravel, water to the half full mark, small samples of algae and any aquatic organisms such as snail or fish.

4. Place a small piece of material over the top of one bottle and secure it with a rubber band.
5. Place the now enclosed end of the bottle top into the bottom half of the other bottle.
6. In the top half place a small amount of gravel then potting soil, seeds and plants.
7. Cover the system with the top half of the bottom bottle.
8. Use clear tape to secure all of the connections between the bottle parts.

The ponds in the bottle were constructed near the beginning of the school year and maintained throughout the year. Over the course of several weeks to a month the systems were watered by the children. When the children observed that the systems were stable (for example, the plants and animal exhibited consistent patterns and relationships) they proposed changes to them. Some of these changes included varying the amount of light or temperature, adding substances such as salt or oil that represented pollution, removing or adding certain species such as snails or insects, or changing the levels of populations such as adding several fish or earth worms.

Children then predicted the outcome of their proposed changes, conducted their experiment, and reported the results through writing, drawing, graphing, or sharing verbally in small groups. For example, one child noted that when she added several snails to the aquatic portion the algae disappeared after several days. Of course, the snails ate all the algae. Another student added several earthworms with no obvious effect.

Water Windows, Classroom Ponds, and Aquariums

After the children had the opportunity to construct their own bottle biology, they participated in a variety of aquatic model building activities. The interest in aquatics arose when one child began sharing with other children about his fish that lived in a tank at home. The teacher also shared this child's interest and brought to school materials that had been collected for model building.

In this project children were introduced to, and participated in, building two different types of water habitats: individual aquatic ecosystems and a classroom aquarium. Children collected information and materials to help them work on their aquatic systems on field trips to local aquatic habitats and the local aquarium store, through books that were available in the classroom, and from the teacher and parents.

Class participation in setting up, maintaining, monitoring, and manipulating the aquaria helped give the children a sense of ownership of their learning and provided a high degree of motivation for subsequent puddle and pond projects. These types of hands-on learning activities fostered the development of science and mathematics skills, and helped the children develop an understanding and appreciation of the complex interactions in ecosystems, as well as practical knowledge about the technology of aquarium maintenance. In the following two activities children built aquatic systems, and observed and recorded how the systems changed over time.

Activity: Individual Mini-Aquatic Ecosystem (jar aquarium)

The first level of involvement for the children involved the construction of their own aquatic ecosystem. This activity relied on easily found, no-to-low cost materials which included the following: medium sized glass jars with tops, sand and grave, water, aquatic plants (collect locally or ask for weed like plants from fish or pet store), snails (collect locally or ask for excess snails from fish or pet store)

Each child placed a small amount of gravel or sand in the jar and filled it about three quarters full with aged water (water that had been left standing for a few days). The activity required about ten gallons for twenty children. They put some of the aquatic plants and two-three snails in each jar. The containers were covered and placed in bright indirect sunlight. Children observed the mini-aquatic ecosystems over a period of several months. Evaporated water was periodically replaced with aged water. Children recorded observations in their journals, included drawings, and noted changes over time. For example, in several jars a light green scum collected at the bottom of the jar while above it grew an intricate maze of branching green algae. Snails in several jars reproduced producing a large number of offspring. Student journals chronicled a wide variety of observations.

Activity: The Classroom Aquarium

After the children completed the jar aquaria, the teacher extended their learning by getting the children involved in putting together an aquarium for the classroom. Once it was set up, the children and teacher made fascinating discoveries and really enjoyed themselves. Fish tanks provided soothing sounds and images which tended to have a calming effect on the children and the teacher. There was also a level of appreciation in maintaining a successful classroom aquatic ecosystem that helped the children develop positive values toward life. The teacher had the responsibility of guiding the process, but the children were responsible for maintaining of the aquarium.

An ideal classroom aquarium set-up included one that was large enough for several children to sit around and make observations. A ten gallon tank is adequate, but larger aquaria provide more area for interaction. The aquarium was placed on a table so that children could sit on all sides of the tank and make observations.

This activity relied on the following materials: fish tank (10-30 gallons works well), aquarium pump (approximately $10), mechanical corner filter (approximately $3), biological under gravel filter (approximately $3), Plexiglas or clear plastic wrap, sand, gravel, water, aquatic plants (collect locally or ask for weed-like plants from fish or pet store), snails (collect locally or ask for excess snails from fish or pet store), fish (purchase from pet store).

The following information is provided to assist with the set up of the aquarium. A pump to supply air to the system should be used. The filtration system is one of the most important factors in the successful operation of a classroom aquarium. In a fresh water aquarium, it is possible to maintain the system with minimum filtration if a balance of plants and animals is achieved. However, to insure success, a combination of two types are recommended: biological filters and mechanical filters.

Biological filtration takes place in the gravel as the water is drawn into a sub-gravel filter and is virtually essential for a successful aquarium. Aquarium animals excrete urea and ammonia, toxic waste products which must be quickly converted to necessary nutrient nitrates by bacteria that live on the substrate above the sub-gravel filter. Nitrates are released to the water through the action of the sub-gravel filter where they are assimilated by plants and move back into the nitrogen cycle of the system.

To assure that there is not too much nitrate available in the system (a condition that could lead to undesirable micro-algal blooms that would out compete other organisms in the system for oxygen and other nutrient resources), one quarter of the aquarium water should be replaced each month to dilute nitrate concentration. Evaporation of water from the tank will be apparent, especially after weekends and school vacations. Be sure to mark the original level of the water when the tank is set up and add aged water to maintain that level.

Mechanical filtration removes particles from the aquarium system, assists in keeping the oxygen levels high, and helps keep the water clear. There are a number of outside filters (those that hang on the top edge of the aquaria) which have power units constructed so that water passes over a fibrous material, such as a porous sponge, and particulate matter is filtered out.

Another inexpensive approach is to use an inside tank corner filter which functions the same way as the outside filter but uses air from an air pump to move the water through the filter medium. Most aquarists find a combination of the two approaches to filtration is best.

An air stone and plastic tubing are used in conjunction with the pumps to provide air to the system. Gravel purchased in a pet store or obtained from a natural site like a stream bed or beach should be thoroughly washed before it is added to the system. Gravel should cover the bottom to a depth of three inches. Water from a natural site or tap water may be used to fill the system.

Both kinds of water should be allowed to sit for at least 2-3 days before adding organisms to the system. Plants should be added first and allowed to establish themselves for approximately 5 to 10 days before adding animals. Cover the tank with Plexiglas or clear plastic wrap and tape down the sides. The cover will help reduce the loss of water due to evaporation, admit sunlight, prevent foreign objects from being introduced, and keep animals in.

After collecting and purchasing the necessary materials for the construction of the aquarium, the teacher spent time discussing with the children the items and their purpose. With guidance and direction from the teacher, those children that were interested assisted in the set up of the aquarium. Once the water was added and the biological and mechanical filtration systems were in place, it was time for the children to consider the types of plants and fish that would thrive in the system.

The teacher arranged a field trip to a pet store, and with the help of the owner, fish and plants were purchased. In addition, samples of algae and snails were obtained for free. Children learned about the importance of algae, plants, and snails to the function of an aquarium. The following information is shared for a better understanding of their functions.

Macroscopic and microscopic primary producers (plants) are essential components of an ecologically balanced aquarium system. They provide food for herbivorous zooplankton and larger invertebrates you may wish to raise or for some fish species you may wish to culture.

Living plants also provide organic and inorganic nutrients to aquarium water that may be directly absorbed by other organisms; and oxygen, a necessary gaseous component of a balanced system, is a by-product of photosynthesis. Dead plants provide nutrients to decomposers, which, in turn break down plant tissue that can then be recycled as system nutrients. Plants also use animal waste products to create new food.

In addition to providing nutrients, rooted and floating large plants provide cover and camouflage for smaller organisms. Certain plants that are easily bought from aquarium supply stores are more hardy and do better in newly established aquaria than do others. Once "conditioned" or balanced as to nutrient flow, other common species do very well and provide diversity to the system.

Micro-algae are as important to a well balanced aquarium as they are in natural aquatic environments. Algae may be collected from ponds or lakes and introduced directly into an established aquarium. Micro-algae are an important source of food for herbivorous zooplankton, such as Daphnia, the common water flea, which are in turn eaten by carnivorous zooplankton and the young of larger fish and invertebrates.

Microscopic and macroscopic invertebrate consumers are an important biological link in energy flow of any aquatic system. They not only serve as a food source for small organisms in the system, but also serve to concentrate and cycle other nutrients, such as nitrogen through the system. Herbivorous zooplankton, like the water flea, serve to check population explosions of algae that could foul an aquarium. Snails serve to prevent fouling of tank sides and bottoms while also serving as a food source for fish.

Once the aquarium was set up and operating, general maintenance required very little class time. Yet, as in any successful aquaculture operation, children learned that there was basic maintenance that needed to be met if plants and fish were to thrive. Children learned about what fish eat, how to feed them, and the appropriate amount to feed them. For example, at one point in the school year the class aquarium was full of a dense algae growth. This was due to an excess of available nutrients.

The students began to feed the fish less and the algae growth was reduced. They also learned about starting a small garden of lettuce plants in a tray, from which they snipped leaves throughout the entire year, dried them, and fed them to the fish. Frequent inspections (daily or every other day) occurred by children who understood how the system operated. For example, plants and fish should be alive and actively feeding and appear in good health. Dead fish should be removed immediately.

Water temperature should be checked and the filter system should be inspected to see that it is operating. A daily log of the date, water temperature, observed activities of fish, propagation, deaths, and other interesting observations were kept in the aquarium journal. The log yielded interesting information and insights into problems which occurred. Reference to the log helped the children understand basic aquaculture principles related to food, growth, and cost/benefits of the system.

After the individual mini-aquatic and classroom aquariums were constructed, the teacher proposed additional activities that promoted science and mathematics skills. The activities stressed skills such as counting, making comparisons, estimating, measuring, and organizing and representing data through graphs. Children also used investigative and observation skills in several of the activities.

Some children counted the number of snails in each of the aquaria and made a graph and noted their comparisons. Some children completed this task weekly and noted the differences over time. As the snails multiplied, it became necessary to estimate the number of snails rather than actually counting them. This activity allowed the children to record the rapid multiplication of snails and count a heterogeneous set.

Some children graphed the number of fish, plants, and snails. They examined the ratio between them. If you have several aquariums in the room you might investigate to see if the ratio affects how healthy the aquarium appears to be.

Other children estimated the amount of water needed to fill the aquarium. As the water was poured in, it was measured. Standard objects of measurement, such as measuring cups as well as other objects such as jars or small containers were used. Children who did not use standard measuring items discussed their results with others and began to see the advantages in using standard measurement.

Some children measured and recorded the evaporation in the aquarium each week. They marked the sides of the aquarium with a wax crayon. The teacher asked them if the amount of evaporation was always the same, and if not to think about what might cause the differences. Some of the reasons that the children noted were "because it is hot," "because the fish drink the water," "it just disappears," and "it goes away." In addition, the teacher shared with the children some other reasons such as decreased humidity, increasing a liquid's surface area, and air such as a fan moving across the surface of the liquid all increase evaporation. The children also experimented with ways of decreasing the evaporation by covering the aquarium with plastic wrap and turning down the temperature in the classroom at night.

With the help of the teacher, the scales of a fish were removed avoiding the lateral line. They were placed between two slides that were then taped together and examined under a microscope set at low power. Children noted that fish have rings on their scales which were similar to tree rings. The teacher had several different types of cross sections of trees for the children to make comparisons. The teacher shared with the children that fish can develop several rings in a year. To determine the age of the fish, the children found the rings that looked malformed or which grew close together. These rings generally indicated the slower pattern of growth which is found in the winter. Children examined the rings and counted them. Some of the children also drew a picture of the scale for their log book.

If you have several aquaria, you might find that some become polluted due to various causes such as overfeeding which happened in one aquarium in the classroom. This led to a discussion of polluted water and how to clean it. The following activity allowed the children the opportunity to develop a hypothesis; test the hypothesis by experimenting with different filtering materials; observe what occurred, and to draw a conclusion. For example, one child noted that she thought the city water treatment plant near her home must take the smelly stuff out of the water before it goes back in the ground.

Children began by filtering water in order to remove impurities. Each child was given milk cartons with holes punched in the bottom and a variety of materials including cotton, fabric, sand, and charcoal. They were given the opportunity to make different kinds of filters in the bottom of the milk cartons using the different materials. After they made their filters, they were encouraged to pour clean water over them to pack the filter materials together. Then they were given jars of muddy water and experimented with the different materials to see which would most effectively clean the water. Children recorded each of their trials and what happened and shared their results with others in small groups. Some of their findings indicated that no process totally cleaned the water and maybe several processes combined were necessary to do the best job.

Classroom aquaria were an excellent hands-on approach for children to experience the interactions of physical and life science as well as the role people played in maintaining water habitats. One of the greatest features of aquarium keeping is that teachers can put as much, or as little effort and money into the systems as they can afford. Anyone can start with a minimal investment in a gallon jar, some sand, air pump, filter, and some locally collected plants and animals.

Related Puddles and Ponds Activities

After the children engaged in the above activities, the project was expanded to include additional interdisciplinary opportunities. The following activities demonstrated some of the ways in which the puddles and ponds project was interrelated with other parts of the curriculum:

Art

To create pictures of their experiences children first needed to visualize those experiences, determine which of those experiences to draw, and then determine how to get their ideas on paper. Children were given opportunities to experiment with techniques, materials, and form in order to express themselves. There are many opportunities that teachers can provide for the children. The following were some that were a part of this project:

A mural of the puddles, ponds, and aquaria was created using a variety of media such as chalk, markers, fabric, various collage materials, and materials the children found on their field trips. To help develop the mood, a tape of brook sounds was played for background music. Some children made initial sketches and kept notes during the field trip to aid in their recollection. As they revisited the puddles, ponds, or aquaria, they added to the mural or created a new mural demonstrating their increased understanding.

Some children became interested in creating a diorama. Children drew a picture of their aquarium or a variety of fish using crayons. Then they painted the picture with watercolors or a thin mixture of tempera paint. The paint did not stick to the crayon, thus creating a watery background.

Many open ended art materials such as a variety of paper, colored markers, pencils, scissors, staplers, and some books with pictures of fish were set out on a table. One child came up with the idea to make a stuffed fish and showed his peers how to do so. After viewing some pictures of fish, he cut out two sides of a fish from paper which he colored. He then began to staple the two parts together and found some newspaper which he crinkled up and stuffed in the fish. He then finished stapling the fish together. Soon children were creating several varieties of stuffed fish. Strings were attached to the fish and they were hung around the room.

Dramatic Play

While engaging in the project, some children became interested in other related topics. Because of the close proximity of many rivers in the area, one such topic that was mentioned by a few children was fishing. Therefore, the teacher organized a fishing prop box which was placed in a section of the room. The box included fishing poles (to which magnets were attached), plastic and paper fish (to which paper clips were attached), waders, fishing vests, hats, sunglasses, fish nets, and magazines about fishing. Through dramatic play the children explored the various props, experimented with roles, and learned about the world around them.

Journaling and Writing

Writing in journals allowed the children to construct knowledge by placing it in their own words. Entries assisted the children in increasing observation skills, collecting and organizing data, and summarizing what they had learned. Entries were written by the children, dictated to the teacher, or tape recorded. Some children included drawings based on their construction of knowledge. Journals included self-initiated entries or responses to the teacher's questions. Because the journals were designed to go with this project, the children decided to decorate their covers with related themes of interest to them.

The children and the teacher came up with several possible journal topics which the teacher wrote on a piece of paper. Throughout the project, the children were given choices on what to write. Some of the topics that were proposed included:

- What does a fish do to move through the water?
- Compare two different species of fish. Make a list of the ways that they are the same and different.
- Examine the body of the fish. How would their movement change if they were shaped differently?
- Describe what parts of the aquarium different fish use the most.
- In what ways are fish and people the same? In what ways are they different?
- Compare at least two different aquaria. What differences do you see?
- Look at the mouth of the fish. How does the mouth affect the way that the fish eats?
- Examine the shape and color of the fish. How do these help fish to camouflage themselves?
- In what unusual places might we might fish?
- What are some things that might hurt fish?
- What words can you use to describe fish?

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The teacher had children in small groups share or read some of their responses to the questions or topics. At other times, children who had written on the same questions or topic were requested to share with one another. This sharing seemed to be of particular value because it allowed children the opportunity to hear other children's perspectives. The sharing often led to discussions and dialogues among the children.

Language Arts and Bookmaking

Several of the children were particularly interested in the books that were available in the classroom related to the project. Therefore, the teacher proposed the idea of creating a group book for the classroom. The teacher began by having a group discussion where children brainstormed what they learned on the field trips, what they saw on the trips, or interesting observations they made. Each fact or observation that children proposed was written on a page by the teacher.

Children who proposed ideas were asked to write or draw about their ideas. After the children completed their work, the book was stapled together and placed in the class library. This experience allowed the children the opportunity to summarize their experiences, to see the teacher modeling writing, and to create and read a book relevant to their interests.

Another form of writing that was undertaken by a group of children involved developing a book that gave directions on how to set up a class aquarium or bottle aquarium, where to go to get fish, and a description of different kinds of fish that were purchased. This assessed the children's understanding of the processes, provided a form of writing where accuracy was important, and gave them a legitimate reason to write. These directions were later shared with another classroom and with the parents during the final puddles and ponds celebration.

Children also got many other opportunities to write during the course of the project. These included writing invitations to guest speakers, writing thank you notes to those who helped with the project, labeling displays, and writing invitations to their parents requesting their attendance at the celebration of the project.

Poetry

Concrete poetry or drawing with words combines both verbal and visual art. The following activities allowed the children to use descriptive words in expressing their feelings about fish and water. The teacher asked the children to visualize an experience that they had with fish or water.

Children were requested to write adjectives describing fish (in the form of a fish if they wished) and their feelings about water (in the form of a water drop if they wished). The children shared their adjectives and the teacher made a chart with the children. This was followed by a discussion whereby children shared their experiences and feelings with the group. After the children engaged in these activities, they were asked to develop their own ideas for poems. The poems were shared with the class and mounted on a bulletin board for other children to read.

Problem Solving and Fine Motor Skills

Because several children had an interest in fishing, problem solving skills were created in support of this area. For example, to increase observation skills, children examined different kinds of bait (for example, live bait and lures with the hooks cut off). Magnifying glasses, microscopes, and paper were available so that the children could observe and record their findings. A chart was also developed where children shared how the live bait and lures were alike and different.

To learn about buoyancy, children examined bobbers, sinkers, lures, and flies. They predicted which would float and which would sink, tested their predictions, and sorted the objects. They looked for common traits among those that floated versus those that sank.

To improve the ability to follow directions as well as increase fine motor dexterity, children learned to tie different types of fishing knots and flies. A mother was invited to the class who was a fly fishing guide and showed children how to tie knots and flies. She talked about the different kinds of flies, what they were made from, and what kind of fish would bite the different flies. Some of the children tied simple knots from shoe strings which was easier than using fishing line.

Phase Three: Concluding the Puddles and Ponds Project

In the last phase of the project children shared their work with their classmates and parents. This allowed them to reflect upon what they had learned, to share in a way that made sense to them, and in a way that others would understand about the project approach. As others viewed and commented on the children's work, it demonstrated that their efforts and what they had learned were valued. Parents and others who reviewed the displays and materials became aware of what the children had learned and discovered some new information themselves.

Children participated in planning the celebration of the puddles and ponds project. The planning allowed them the opportunity to brainstorm ideas and problems that might occur, achieve consensus, and make and carry out plans. In planning the celebration, the following steps were included:

- The children and the teacher spent time discussing and listing what had been learned. Some of the things that the children noted were soil and water are connected and have an effect on each other; plants and animals constantly interact in nature, and people can have a big effect on the quality of water. The teacher grouped the similar items and created a summary of experiences and what was learned.
- The teacher and the children brainstormed possible items to share with the parents such as the journals, art work, dioramas, aquaria, bottle biology displays, graphs, and logs.
- The teacher and the children brainstormed the ways these items could be shared, such as individual children presenting a favorite journal entry to the whole group or setting up displays which guests could examine.
- The teacher and the children brainstormed possible activities for the open house. The following were mentioned by the children: making bottle aquaria with their parents to take home using the directions which had been written by the children; playing a game created by the children such as fish trivia and the card game "go fish"; and eating a snack of fish crackers.

After the brainstorming, the ideas were examined in regard to the following questions that the teacher proposed to the children. These included such things as: Will the guests be interested? Do we have the skills needed to complete the idea? Is there enough time to prepare? Is there enough time to present? Do we have enough money to accomplish the ideas? Do we have the physical space needed?

After examining the brainstormed items in regard to the criteria, the items and activities were chosen that would be shared, as well as the way in which they would be shared. In fact, it was decided that most of the ideas proposed would become a part of the celebration. In addition, groups of children were formed to work on various tasks such as creating invitations, collecting materials, and labeling and setting up displays.

The teacher also decided to create documentation panels (Edwards, 1993) which showed the processes that were involved in the project and what the children learned. The children were also involved in choosing what was included in the panels. The panels were made from poster board and included the following items: a copy of the curriculum web with an explanation; photos of children engaged in activities; transcriptions of the children's remarks as they engaged in discussions and activities; the teacher's notes as the project proceeded; and samples of journal entries demonstrating increased understanding.

In order to accommodate the parents' varied schedules, the teacher and children decided to host the celebration on several days. The days chosen were a school day, one weekday evening, and a Saturday. Most of the children attended all three of the selected days. The advantages of hosting several days of celebration were that small groups of parents came on each of the days. The smaller groups provided more opportunities for the parents to interact with the children and teacher, and view the children's work and classroom displays. And a few of the parents played the card game "go fish" as they munched on the fish crackers.

Conclusion

Most children enter primary school with an interest in water and living things. Teachers can extend these interests in children and help move them toward a more sophisticated understanding of scientific and mathematical concepts through the puddles and ponds project. Maintaining aquatic systems in the classroom provided an excellent model of interaction between people, water, plants, and animals, and emphasized the relevance of nature and understanding. The project proved to be a valuable and fun learning experience for everyone involved including the teacher, children, resource people, and parents. The aquatic project is doable for teachers with a little imagination and creativity, and with the suggestions and ideas from the children. Because children's interest are varied, a puddles and ponds project has the potential to move in many different directions.

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Chapter 19

Hot Dog Stand Project

Jan Granse

My third graders were plodding through a traditional textbook unit on counting money and making change when the Hot Dog Stand project started. It was a harder than usual class in several ways. The students were more difficult to motivate, had more behavior problems, and presented a broader range of skills, from "at risk" to gifted, than usual. I was becoming frustrated with students who refused to complete their work, failed to pay attention, and disrupted the class. I was discouraged by the blank stares of the students who were unmotivated and the equally glazed eyes of the two gifted students who already had mastered these skills. I had differentiated curricula for gifted students for several years, but this class made so many demands on my time that I had not yet managed to start assessing and individualizing their activities. I had already tried cooperative learning activities, games, using real money—all of the tricks in my bag. These strategies helped, but students were still off task much of the time and were not able to demonstrate adequate progress, or a significant amount of what they knew.

Every morning, I enter the building through the hall that passes the kindergarten rooms. I have often chuckled at the charming cardboard box and toilet paper roll constructions that line the hall and represent everything from fire trucks to factories. The kindergarten teacher is a friend of mine who uses projects in her classroom. We had discussed the project approach and I thought it sounded like a wonderful idea—for kindergartners.

Week One

One day, our elementary physical education (P.E.) teacher announced a baseball card show to be held in the school gym. Students in grades 4-6 were invited to set up tables and sell and trade their baseball card collections. My students didn't understand at first that their grade level was not included. They came back from P.E. one day full of excitement and big plans for the card show. I hated breaking the news to them. I really liked the way their enthusiasm felt to me. But, I still had to tell them, and of course, they were disappointed and irate. It was then that the idea for the hot dog stand emerged. Students with card collections wanted to have their own card show in our classroom. This suggestion stimulated protests from the non-collectors. The next thing I knew we were brainstorming about what kind of project we could do that would relate to the card show without directly participating in the events in the gym. During a large group discussion, I recorded their ideas on chart paper. The suggestions were getting bizarre—like, stand in the parking lot with their own cards and "steal" customers as they entered the card show. The idea came from one student's experience with a ticket scalper at a college basketball game. I suggested that we offer to make posters to help the older students advertise. The class had absolutely no interest in my idea. At my suggestion, we started a list of everything that had any connection to baseball cards. This led to what we liked about baseball games. The concession stand was mentioned, and then hot dogs. There it was. From the moment the idea of opening a hot dog stand during the card show was mentioned, the topic had its own momentum. I stopped the class with a "wait and see" attitude pending approval from the P.E. teacher and the administrators.

Our district is small and informal. Submitting a proposal and getting administrative approval is as easy as stopping the principal in the hall and saying, "I've got a great idea." The

P.E. teacher immediately loved the idea and the administrators enthusiastically supported our plan. None of us knew that the hot dog stand would grow to be a four week multidisciplinary project that would take us out into the community. The description of the next four weeks sounds more orderly than it actually was. The reality is that ideas were generated by students in a much more random manner. The overall "life" of the project did progress through the three main phases of project work, however (see Allison, this section). The remainder of this chapter is a narrative account of how the project evolved, rather than a listing of activities under each phase. As you will see, the project entailed many discussions that were critical to the project's success.

So, we're going to open a hot dog stand. How will we go about doing that? We made a who, what, when, where, how, and why chart. Who? Mrs. Granse's third grade class. What? Open a hot dog stand. When? On the day of the card show from 10:00 to 1:00. Where? This question required discussion. The first plan was to set up the stand outside the gym on the playground. Students wanted to bring barbecue grills and coolers. They would cook hot dogs and sell pop out of the coolers. Several children were skeptical about their mothers letting them use charcoal. Someone else asked about weather during the month of March in Illinois...new plan!

The next plan was to set up a table in a corner of the gym. They would cook the hot dogs in a microwave and could still use coolers for the pop. They felt that their moms would be more likely to let them use a microwave. Someone mentioned the "no food or drinks in the gym" rule...new plan! Our classroom is adjacent to the gym. There is a hall with bathrooms and a water fountain just outside the entrance to the gym. Students decided that this would be the perfect location if we could turn off the water fountain so it wouldn't reduce their pop sales.

The "how" question stimulated the most discussion. We concluded that we needed to find out more about running a food service. I became a questioner, a prober. I wondered aloud about who we might ask for advice. Students suggested that we ask the cooks in the school cafeteria or the person in charge of the concession stand that is open for school athletic events.

I continued to probe. Who could we ask outside of the school? A student thought of the man who owns the local pizzeria. Pizza Man is a favorite place for Villa Grove children and they were enthusiastic about enlisting his help. We agreed that I would call him and ask him to come to school and talk with us about how to set up a food service. Then we addressed the "why" question. I, of course, hoped they would say so we can learn to count money and count back change. They were interested only in making a profit. It was immediately apparent that my curriculum objectives could be met in the process of meeting their mercenary goals.

Week Two

I called Pizza Man and arranged for the owner to visit our class. He called back a few days later and suggested that it might be better for our class to come to his restaurant so he could show us how his business works. He offered to provide free pizza and Coke, a tour of the restaurant, and time for students to ask him questions about how they should proceed. Our school is located a few blocks from the business area so we walked to Pizza Man for lunch several days later. As we toured the restaurant he emphasized the need for cleanliness and the role of health regulations. He explained how all of the equipment worked and the role of each employee. He demonstrated how they controlled the quality of each pizza by weighing the ingredients.

Then he seated them in his party room and served them pizza while he talked with them about his business. He began by telling students about how he started Pizza Man on a "shoestring" budget, and what that meant in simple economic terms. He further explained how he built it into a successful business over the years. He spoke with them frankly about his mistakes as well as his triumphs. He told them about the people in the community who helped him along the way, including how he financed his first restaurant. He spoke about careers in the food service business—about training, how much money you can earn, the kinds of jobs you might do. He told them about a scholarship he provides every year to an interested high school student at a nearby community college. He explained that he decides what percentage of his gross he will spend on salaries, building, supplies, and other expenses.

Next, he asked them to tell him about their business plan. They told him the plan so far. He asked them where they would get the money to buy hot dogs, buns, pop, ice, etc. They didn't know yet. He explained how he went to the bank with his idea and they loaned him the money to start his restaurant. He also talked about how some people get private investors to put up money. Their last question was, "How much money do you make?" He answered frankly, with no hesitation. It was fascinating to witness an example of students making a connection between knowledge about economics, careers, and roles people have in the community.

Back in the classroom we explored some of the mathematics concepts that had been introduced at Pizza Man. We used Unifix cubes to demonstrate percentages. We applied what we knew about place value using the big numbers that had been mentioned when talking about Pizza Man's gross and profit. We had to expand two new decimal places because third graders had not yet learned how to handle numbers that large. We practiced recording large amounts of money with numbers, dollar signs, and decimal points. We didn't master these concepts but rather focused on exposure as we were way beyond the content of third grade curriculum. However, I had at least two students who had a very good grasp of the concepts and most students understood the general idea.

The class decided to ask for a bank loan for start up money. The bank president's son was in the class and he was quick to volunteer his father's services. They arbitrarily decided to ask for $30.00. A lot of estimation led to this amount of money, however. The estimation was based on discussions addressing these questions: How many people do you think will be at the card show? How many people do you think are likely to buy hot dogs from us? How much do you think it will cost to make a hot dog? How much to buy a can of pop? How much money do we need to start?

After contacting the bank president, he agreed to visit our classroom. During his visit, he asked students about their business plan that justified their need for a loan. He talked about why they did not include enough information to get a business loan. He explained how loaning money is a business and the bank charges interest on the loan. He spent a considerable amount of time trying to explain interest. I knew they understood when they became outraged that they would have pay to back more than they borrowed!

From there, he introduced other kinds of loans. He explained that personal loans required security. He talked about how the bank tries to help people when they have trouble paying back loans and how the bank prefers to not have to take the security as payment. Then he suggested that we prepare a more detailed plan, fill out a loan application, and visit the bank to finish the paperwork. He agreed to support our attempt to get a loan.

We filled out papers for a personal loan. We had a time problem, unfortunately. We didn't have a complete enough business plan for a business loan and if we finished the business plan before we applied for the loan, it wouldn't be processed in time. The bank president would have gladly pulled the money from his own pocket and handed it to us but I asked him privately to keep it real. We wouldn't learn as much from such generosity as we would from the reality of the situation. Students were taking the project very seriously!

The problem was that a personal loan required security. We needed something worth $30.00 to secure the loan. Everything in the room belonged to the school except the classroom pet hamsters in a glass aquarium. A parent had donated it to our class earlier in the year. With some anxiety, students offered the hamsters as security on the loan with knowledge that if they were unable to repay the loan the bank could take their beloved pets. The loan papers said, "two hamsters, cage, toys, and all accessories and food products". The bank president's son reassured the class that if the bank took the hamsters as security, his dad's secretary would take good care of them and we could go to the bank to see them.

We walked to the bank and were given the grand tour. The most popular parts of the tour were seeing the change counting machine work and walking into the safe. The bank president explained careers in banking and talked about how much mathematics his employees had to use to do their jobs.

Next, he ushered students into the board room. They sat around the big wooden table with their chins about table height and negotiated the loan. The bank president was wonderful. He had his secretary bring in the loan papers and they were passed around the room for every child to sign. It was a very solemn moment as students had been fully advised of their responsibilities as borrowers. The loan was approved. When we received the money we placed it in the school safe. To students, it was a lot of money and responsibility.

Week Three

Back in the classroom, we compared percentage as it related to interest on our loan with percentage as described by the pizzeria owner regarding what part of his gross income he allowed for salaries, supplies, building, etc. We used pennies and dollars to understand the money we would spend on interest. We were paying 9%. If we borrowed one dollar, we would pay back one dollar and nine cents. How much would we pay back if borrowed two dollars, and so on.

In cooperative learning groups, we figured how much money we would owe the bank. We discussed how a change counting machine made counting change easier by sorting it first and how we could use that idea to make it easier to count change when we were selling hot dogs. We started counting change by first sorting it into pennies, nickels, dimes, and quarters. Some students began to experiment with other ways to sort the change for easier counting. Some grouped change in stacks worth $1.00 each. Others grouped in stacks worth a quarter each. All students learned that money is easier to count if you sort, group, or organize it in some way before counting.

There was some dissension about what to sell at this point. Ideas were flowing, changing, and expanding. Some students thought we could make more money by selling nacho chips and cheese sauce. Some thought we should sell Pepsi and some thought Coke would be better. I, being the prober, asked how could we find out. We can't afford to guess. The stakes are high. Our hamsters are at risk. Students decided to take a survey on the playground. They reasoned that most of their customers would be elementary school children who either had card tables set up in the gym or were customers at the card show. They went to recess with clipboards and pencils and tallied preferences of several food and beverage choices that they had listed earlier in a brainstorming session.

Back in the classroom we combined their data and made two graphs, one showing food preferences and one showing beverage preferences. From the data we concluded that hot dogs and Hi C juice boxes would be the best sellers. During the graphing activity, the students answered questions like, "How many more students chose Coke than Pepsi?" "Which food was chosen by the least number of students?" "Which drink do we definitely not want to try to sell?"

At this point I became uneasy about the amount of time we were spending away from the curriculum and I started to pay careful attention to opportunities to include skills and concepts that we would be expected to master in third grade. We measured the hall where our hot dog stand would be located and drew a diagram. We also measured furniture in the classroom that we thought we could use for a serving counter, cooking area, and seating for our customers. I also became very conscious of making sure that all of students participated enough to get experience with measurement. We set up tables in the room to determine how much space we needed for people—for a cooking area, for a line of customers, for a group of customers to put ketchup and mustard on their hot dogs at a condiments counter, etc. The floor plan was finalized on paper.

In the process, we had reviewed units of measure, linear measurement, and area. Students would use tables from the classroom for a serving counter and cooking area and would use the student desks and chairs in groups of four along one wall to make booths. We would have seating for 24 people.

Students started to get ideas for a name for the hot dog stand. They generated ideas and I wrote all suggestions on the chalkboard. I asked what should a good name for a hot dog stand do, and be like. We compared our list with names of successful businesses like Burger King, McDonalds, Pizza Hut, and so on. The students decided that it should be short and should make you want to eat there. They also liked the idea of the name providing a theme for the design of the stand. Using their criteria, we selected the best possibilities from our list and voted for the favorite.

The winner was "The Hot Dog House." The name of the stand and the design possibilities emerged simultaneously. By the time the name was chosen, several ideas for the design of the stand had already been discussed. I listed available materials on the chalkboard and the students, working in groups, drew designs for the Hot Dog House's main serving counter. The plans from the groups were posted and students discussed each one in terms of appeal and practicality. Some changes were made, some ideas combined, and a final design resulted. When opinions differed, we used class votes to make choices.

Students used a table for the bottom of the stand and made a banner with butcher paper and 1x2 inch boards, 8 feet long for the top. The table was set in place, and the banner was hung from the ceiling above the table with heavy string. The banner was shaped like the roof of a dog house and had "The Hot Dog House" written in large letters. The table was skirted with paper and painted to look like the main part of the dog house, complete with a door and a dog looking out. The workers stood behind the table with the banner (roof) hanging over their heads. It was a very clever design made with little more than butcher paper and tempera paint.

Students started bickering over who would cook, who would take orders, who would be cashier, and who would clean tables. We needed a fair way to assign jobs. The students liked the idea of drawing sticks, our usual classroom procedure when we need a fair way to decide something. I asked what if someone who is cashier isn't very good at making change. Students saw immediately that their profit could be negatively affected by this. They recalled that the pizzeria owner said his employees filled out an application form and he interviewed them. So, we made a list of the jobs we thought we would have to fill. Then we used the overhead to make a job application that also required references. I was chosen by students to conduct interviews and hire managers for each of the four shifts.

I interviewed and "hired" children who could demonstrate mastery of counting money and making change, explaining that the manager of each crew would have to be able to train his/her crew. Then the managers looked at the rest of the applications and "hired" their cashiers, cooks, and cleaners. Children indicated on their applications which job they wanted. In most cases the managers were able to give them at least their second choice. Some children were not confident enough to apply for manager or cashier. The most sought after job was cook.

Later on, I kept the managers in during a couple of recesses and I trained them to wait on customers, make change, and clean tables and the floor. They had to train their crews. The managers found that leadership was often a heavy burden. Some of them were frustrated by their choices of crew members. Together we made work schedules and made sure that all crews had equal time on the job. Several problems involving time were worked out in groups of four as they perfected their schedule.

What time should we open? When should we close? How long should each shift be? If we had four shifts, what times would they change? Would each shift get the same amount of time? I asked how they would advertise their business. They decided to make posters and to put an ad in the local paper. We didn't know much about placing ads so we decided to call the local weekly paper. This time, we asked for a tour of the newspaper operation. The publisher met us there, showed us how ads are processed and prepared for printing. He explained how ads are priced by the word or by the column inch. Then he let us watch while he ran a page of that week's paper through the antique press still used to print our paper. He also talked about careers in the newspaper business.

Back in the classroom, we established an advertising budget of $2.00 and began to experiment with advertising copy. Who could give the most information with the fewest words. Which would be cheaper, by the word or by the column inch. We started using calculators for operations that were otherwise beyond their skills. Students wrote dozens of versions of their ads. They checked each other to be sure all of the important information was included. They figured the prices, reworded them, and figured the prices again. They measured column inches, made drawings, reduced drawings, invented borders, enlarged artwork, until we had dozens of potential ads. They increased the advertising budget to $6.00 because they found it impossible to include artwork in a $2.00 ad. The class voted to select the ad that would appear in the newspaper and the designer of the winning ad mailed it to the newspaper office.

Committees started producing posters in their free time, borrowing ideas from the ads that were not published. At this point, students were working on ads, posters, the banner and table skirt for the serving table and other parts of the project whenever their classroom work was finished. Sometimes they stayed in at recess, and frequently they worked in any free time they could find. They were also teaching each other to count money and make change. They were choosing to do this in their free time because it was now meaningful to them.

We started comparison shopping for our hot dogs, buns, and Hi C. We walked to the local grocery store where the owner took us on a tour. She explained unit pricing and how she uses percentage to mark up products to make a profit. She talked about overhead costs in her business. She showed students where hot dogs, buns, and Hi C were located. They recorded the prices of each. Students left the store impressed by how much mathematics was used in the businesses they had been visiting. We were too pressed for time to follow up on all of the mathematics learning opportunities, so we focused on unit pricing because that would be most useful to us as we compared prices.

In the classroom we designed a comparison chart for hot dogs, buns, and Hi C boxes. We included a place for the price per package and the price per piece. The students were asked to visit grocery stores over the weekend with their families and compare prices on the products we would need. On Monday, we compiled our data and used calculators to figure the price per hot dog, price per bun, and price per drink. We chose the cheapest sources and arranged for a parent volunteer to pick up our groceries for us later in the week. In groups of four, students used the prices to figure out our cost for a hot dog and a Hi C. They also prepared recommendations for what price we should charge. There was much discussion about how much money their customers would have and would be willing to spend on food. Each group shared their results.

In the end, they reached a consensus that they could make a profit and still offer a good deal if they charged $.75 for a hot dog and $.50 for a Hi C. The next problem was how many hot dogs and drinks will you have to sell to make enough money to pay your loan off? How many would you have to sell to pay the newspaper bill? How many would you have to sell to make $30.00 profit after the loan and the newspaper bill are paid? How many hot dogs and drinks can we buy with the $30.00 we have borrowed? In each case, the groups shared their strategies and answers and the class reached an agreement about what to buy with the $30.00.

By this time, we entered the fourth and final week of the project and the anticipation mounted. The stand was finished, the posters hung, the ad appeared in the paper, workers were trained, and schedules were posted. A parent suggested that we use slow cookers to prepare the hot dogs and volunteered to loan hers. Students prepared hot dogs for lunch one day as they learned to cook and serve. They used one slow cooker to boil hot dogs and another to keep them warm. On Friday afternoon, they moved the booths into place, set up the work areas, placed the Hot Dog House banner and counter, set up a cash box, and decorated the walls with menus, posters, and streamers.

On Saturday morning, at 9:00, we opened for business. The first shift had very little business. They happily found plenty to do, however, icing the drinks, cooking the first batch of hot dogs, wiping tables, and sweeping the floor. They counted the change in the cash box several times. They lined up the Hi C boxes and counted them. They lined up the buns in neat rows and counted them. They folded napkins, arranged and rearranged the condiment table, and made signs for the bathrooms that said "employees must wash hands before returning to work."

The second shift started at 10:00. From 10:00 to 11:00 we had a slow but steady stream of customers. Fourth, Fifth, and Sixth Graders came from the card show to eat at The Hot Dog House. They thought it was really cool and wished they had been able to do it too. They were patient with the younger students' slowness at doing the mental mathematics and making change from their purchases. Sometimes they would offer helpful advice, like think of how many dollars first, then do the parts of dollars and put it all together. Sometimes they would simplify their orders to make the mental mathematics easier. One sixth grader ordered two hot dogs and paid for them. After he got his change he ordered a Hi C and paid for it separately. He thought that the mental mathematics would be too hard for third graders if he ordered it all at once. We had a surprising number of adult customers. They were gracious and patient as occasionally a hot dog or bun would hit the floor, or a customer would be charged twice or charged and not served, or would bite into an ice cold hot dog.

At 11:00, the third shift came on duty. The lunch rush started, which we had not anticipated. Students who were finished with their shifts but were still hanging around were drafted back into service. Customers were lined up all the way to the gym. Most of the bank employees chose to come to the Hot Dog House for lunch. I can't help but wonder if they thought they might actually get stuck taking care of those hamsters! The workers had to really hustle to

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keep up. Although they had been assigned jobs, they found that they had to be versatile and everyone ended up doing a little bit of everything. The crew managers became assertive and barked orders like seasoned veterans of the fast food services. The cleaners, cooks, and cashiers sometimes took offense, just like in the real world. One manager cried and I had to step in and help for a while, but he came through in the end.

We started running out of food before the third shift finished. We had one more shift to go and the thought of them missing out on the action was too much. I sent my husband to the store to buy more hot dogs, buns, and Hi C. He made three trips before we finally slowed down. The fourth shift still served a trickle of customers, but they had time for clean up. When we closed our restaurant, the coolers were empty, there were several broken hot dogs in the bottom of a slow cooker, empty bun packages were piled under the table, and the cash box was too full to close.

On the following Monday, we wrapped up the project. First, we dumped the pile of money on the classroom rug. Students took turns sorting it, making piles, and counting it. That pile of money was probably counted 100 times by noon. We had receipts from my husband's grocery store trips and we took out money to repay him and put it in an envelope. Then we packed our box of money and headed for town to pay our bills. We went to the newspaper office first. The kind lady at the counter waited patiently while two of students counted out $6.00 in small change, sorting it by coins, putting it into one dollar stacks, then counting out six stacks. They couldn't part with the green stuff.

Then we walked across the street to the bank. Two students counted out the money to repay the loan. They did use some of the bills because they were overwhelmed at the thought of counting out thirty dollars in change. The bank president congratulated them on the successful business venture and personally did the paperwork to close out their loan. With our money box and loan papers in hand, we returned to school to celebrate. Of course, the money had to be counted again because...well, they just wanted to. Their profit was nearly $200.00. We ate the sparse leftovers and burned our loan papers in celebration! The money was used to buy a parachute for elementary P.E. activities.

Summary

The hot dog stand and card show became traditions in our school. Students anticipate it eagerly. When last year's second graders entered third grade this fall, the two things they were most excited about were getting lockers and doing the hot dog stand, in that order. Each year the project has changed to reflect the choices and preferences of the class in charge. One was named Dogs for Sail and they decorated it like a sailboat. Another year was The Road Kill Cafe.

Conclusion

I enjoyed the way the activities provided for the range of abilities in my class. The more able students found challenges and enrichment while the less able found purpose in the practice and repetition. Skill and concept development went way beyond my original expectations when we discussed interest with the bank president, unit pricing with the grocer, percentage with the pizzeria owner, and column inches with the newspaper editor.

Although the project has become better in some ways as it has been repeated for the fourth year, it has also lost some it's freshness. The first year the ideas came entirely from students, taking all of us by surprise. They were in unknown territory and it was a great adventure in the real world with a real possibility for failure. Now, students know all about it from older siblings who have done it and from being customers in previous years. The class is influenced by what has been done before and they haven't really departed greatly from the original project. The popularity of baseball card shows has decreased and there probably won't be one this year. There will, however, always be projects. I am convinced that they are not just for kindergarten.

It hasn't always been easy to let them go with their ideas, especially when they chose to decorate with flat animals and tread marks. Each year I have become more comfortable with replacing some of the existing curriculum with activities connected with the project. I made a list of skills and concepts in the basic curriculum and I check them off as I feel students have had ample opportunity to learn them.

I also have improved the connection to the science and language arts curriculum. We write thank you letters to the people who help us. The children make the contacts with the businesses in town who participate. We write advertising jingles and radio spots. We have done science projects about food spoilage, bacteria, and refrigeration. We recycle the packaging from our products. We use Earth friendly serving materials—no more plastic or styrofoam. The possibilities for cross curricular activities are infinite.

Looking back now, my original objectives seem a little trivial. At first, I wanted students to count change up to a dollar and make change in amounts less than a dollar. However, during the project we were *immersed* in money issues, which is more than just learning simple skills. We counted hundreds of dollars, performed operations with money, calculated profits, estimated, predicted, calculated mentally, used a calculator, gathered data, made graphs, drew conclusions based on analysis of real data, and measured, diagrammed, and solved difficult mathematics problems. We also learned much about how the adult world works—about the self-made pizzeria owner, how the bank makes a profit, risks associated with borrowing money, and personal responsibility to a group. They were introduced to careers in the businesses associated with our project and they connected with our community leaders.

What was perceived as important to students? They redeemed their hamsters, and they made a big pile of money!

About the Author

Jan Granse received her B.A. in Art Education in 1975 and her M.A. in Art Education in 1985, both from the University of Illinois in Champaign-Urbana, Illinois. She taught K-12 art for nine years before transferring to a third grade self-contained classroom where Jan has continued to teach for the past 12 years.

Section 5

Integration

This section continues the exploration of integration of content areas and method. In Chapter 20, Susan L. Westbrook describes advantages and methods of integrating science and mathematics. She presents the *Shadows*, the *Seeds and Fractions*, and *Patterns* investigations; these learning experiences use the learning cycle to integrate content areas.

Anita Roychoudhury and Iris DeLoach Johnson present instructional guidelines for integrating science and mathematics. They present a series of detailed food and energy lesson plans that integrate these areas using the learning cycle. The learning experiences of Chapter 21 include: Lesson 1: Food Groups; Lesson 2: Meals; Lesson 3: Food, Calories, and Energy; and Lesson 4: Bodies, Food, Cars, and Energy. The lessons include auxiliary activities.

Jan E. Downing and Tammy Benson explain the important role of literature in early education in Chapter 22, "Literature: Keys to Learning Mathematics and Science." They present advice for finding and evaluating quality literature. Downing and Benson present 20 activities and 4 lesson plans to integrate literature, science, and mathematics. The chapter includes a bibliography of quality children's literature organized by science topic.

Diana Stevenson and Cyndi Broyer in Chapter 23 present a soup-to-nuts account of creating and using Math/Lit Kits. These kits help parents and children learn about mathematics through literature connections. The authors explain how to select books for the kits and how to develop and write appropriate activities. They present examples of kits successfully used in early childhood education.

In Chapter 24, Michael L. Bentley, Stephen Bloom, and Virginia Reynolds describe the benefits of field-site experiences and explain the Interactive Experience Model. The authors describe how to create an environment that promotes inquiry. They present a detailed account of wonderful integrated learning experiences in a grocery store including information on organizing the field trip, providing structuring activities, pre-trip activities, on-site activities, and post-trip activities. The authors discuss purposes and methods for assessing and evaluating the field trip.

Where do you find integrated materials? Kimberly S. Roempler and Marsha Paulus-Nicol answer this question in Chapter 25. They describe many well-developed materials for teaching science and mathematics and explain how to use the ERIC Database and the Eisenhower National Clearinghouse to find these resources.

In the last chapter, Peter Rillero explains the benefits of using integrated teaching methods in early childhood education. He reviews definitions of activity series, activity centers, and projects and gives examples from this book of their effective use together and with other methods of instruction.

Chapter 20

Integrating Science and Mathematics Content in the Elementary School Classroom: Beyond Coordination

Susan L. Westbrook

National committees and teacher organizations are advocating fundamental shifts in the philosophies that underlie the way many teachers think about teaching science and mathematics. The goals of the National Council of Teachers of Mathematics' (1989) *Curriculum and Evaluation Standards* include valuing mathematics, communicating mathematically, and reasoning mathematically. These standards encourage a movement away from emphasis on computation and memorization of number tables in the early grades. The National Research Council (1995) identifies inquiry as an important component of the science curriculum at all grade levels and in every area of science. Again, we see a shift from traditional instructional methods that rely on reading, teacher-given information, and worksheets. Documents from other government agencies advocate science and mathematics for all children, learning theory based on the premise that children construct their own knowledge (constructivism), and the use of developmentally appropriate materials in the classroom (Lacampagne, 1993; Sivertsen, 1993).

How does one teacher in one classroom manage to address the demands being placed on school instruction? How can the classroom environment be structured to allow for meaningful investigations in mathematics and science and also address all the other mandates (e.g., cooperative learning, teaching for diversity, learning styles)? The answers to these questions are dependent on the teacher and the classroom environment which is developed, but integration of science and mathematics content within the context of rich, meaningful inquiries can take that teacher a long way toward accomplishing the goals set for the classroom.

Why use an integrated approach to curriculum and instruction? Integration of content across curricular boundaries can be defended from several different perspectives. The nature of scientific and mathematical practice provides a philosophical framework for integrating these disciplines within the classroom. According to the American Association for the Advancement of Science document, *Science for All Americans*, "Science provides mathematics with interesting problems to investigate, and mathematics provides science with powerful tools to use in analyzing data" (Rutherford & Ahlgren, 1990, p. 16). Scientists rarely do the work of science without availing themselves of mathematical concepts. Likewise, mathematicians often use scientific phenomena as starting points for their deliberations. Integrating mathematics and science in the early grades can potentially provide children with a better understanding of the connections between the disciplines and the concepts inherent within those disciplines.

Perhaps one of the best reasons for developing and implementing an integrated approach to teaching mathematics and science content can be found in Ball's (1993) description of the role of the mathematics teacher:

> Teaching is essentially an ongoing inquiry into content and learners, and into the contexts that can be structured to facilitate the development of learners'

> understandings. Selection of representational contexts involves conjectures about teaching and learning founded on the teacher's evolving insights about the children' thinking and her deepening understanding of mathematics. (p. 166)

Representational contexts are the "models, examples, stories, illustrations, and problems that can foster mathematical development" (Ball, 1993, p. 159). Content integration provides the mathematics teacher with two important instructional advantages: the development of representational contexts to help children begin to use mathematics as a conceptual problem solving tool and the daily application of mathematics tools, skills, and concepts. Content integration from the science teacher's point of view is a means to have access to numerical devices and concepts that assist the children's understanding of scientific phenomena. For example, data on a chart are of little value for a "big picture" understanding of the relationship between two variables. However, a graph can act as a vehicle for those data to be represented in a way that allows the child to visualize relationships.

Information from general educational research such as Gardner's (1983) theory of "multiple intelligences" and current interpretations of brain research (Cohen, 1995) lend additional support to integrating, rather than separating, the curriculum. Complex, context rich experiences have far more potential to disequilibrate learners and encourage conceptual development than do more traditional, single-content, activities. Integrated curricular programs have the potential to increase children's abilities to access and use the information they have been learning and to draw on their earlier experiences.

Models of Integrating Science and Mathematics Curricula

What does curricular integration in the classroom look like? When discussions about integrating science and mathematics curricula occur, there are probably as many different ideas about the possibilities as there are people in the discussion. That variation likely stems from divergent understandings about the reasons for integration, goals of integration, nature of mathematics and science content, and ways mathematics and science content should be taught. Davidson, Miller, and Metheny (1995) proposed five different models of integration to answer the question, What does integration mean? The models ranged from "discipline specific integration," focusing on the interrelationships among content within a particular discipline, to "thematic integration," involving the overlap of major topics across several disciplines. Other models of integration included "content specific integration" (integration of existing lessons in mathematics and science), process integration (real-life investigations), and methodological integration (based on the teaching method).

In their description of the various models of integration, Davidson, Miller, and Metheny also suggest that integration of mathematics and science content can be accomplished through use of the learning cycle method. This vehicle for integration has also been proposed by Westbrook and Rogers (1995). The learning cycle (Karplus & Thier, 1967; Lawson, Abraham, & Renner, 1989) provides a malleable instructional model that allows the teacher to develop an investigative classroom atmosphere and an integrated curriculum while still attending to particular concepts in science and mathematics. The learning cycle consists of three sequential—and inseparable—phases: exploration, conceptual invention, and expansion.[1]

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[1] Note: Historically, what is here referred to as the "expansion" phase was labeled "discovery." The term "discovery" occurs less frequently now, but is still used in the *Science Curriculum Improvement Study* [SCIS] materials produced by Delta Publishing. The "conceptual invention" is currently referred to as "term introduction" by Lawson, Abraham, and Renner (1989). "Term introduction" implies to the author that the chief goal of the second phase is to introduce terminology. The author chooses to use the designation "conceptual invention" as it implies that the purpose of the second phase is the invention of the concept by the students.

The class begins a learning cycle investigation by gathering data related to the concept that will be developed. This phase is called the *exploration*. The exploration is followed by the *conceptual invention* discussion. The data from the exploration are placed on charts, transparencies, or chalkboards for the entire class to view. The teacher then leads a discussion of those data. The goal of the discussion is for the children to invent the concept through their own interactions with classmates, the teacher, and the data. This process is accomplished by allowing the children time to think about and discuss patterns and variability in the data set. Once the children negotiate the meaning of the data, a short summary statement is generated by the children and recorded on a chart (or other medium) in the classroom. The invention discussion is succeeded by the *expansion* phase. The purpose of the expansion is for the children to use the concept and language invented in the preceding phases by engaging in further investigations related to that concept. A wide range of opportunities can be made available to children during the expansion phase. The children will benefit greatly from opportunities to design and conduct their own investigations in attempts to answer questions they have generated during the exploration and invention discussion phases. Field trips, speakers, and related reading are also common expansion activities. Regardless of the format, the expansion provides a place in the instructional sequence in which the children and their teacher can further generalize and apply the target concept.

What aspects of mathematics and science content can realistically be integrated? Many educators believe that certain concepts are peculiar to mathematics or to science and, thus, cannot be integrated through classroom instruction (Underhill, 1995; Brown & Wall, 1976). Other authors have postulated a similar dilemma with respect to integrating mathematical and scientific processes (Lonning & DeFranco, 1994). In this chapter, two mathematics concepts generally taught as isolated entities—fractions and angles—are integrated with two (perhaps unlikely) science concepts—seed germination and shadows, respectively. The investigations reflect the emphasis the NCTM (1989) *Standards* place on the use of manipulatives in the teaching of mathematics in the primary grades and the attention science teachers are encouraged to give to inquiry and open-ended exploration. In each case the learning cycle will be used as the instructional model for teaching the concepts. The investigations will, however, illustrate different perspectives concerning the integration of mathematics and science content. *Shadows* will serve as an example of an investigation of daily changes in outdoor shadow lengths and positions will be used to show how length and angle measurements can be integrated within the science curriculum. Through these measurement and construction activities, children will begin to build rudimentary understandings of the concept of angles as well as make sense of scientific phenomena. A second investigation about seed germination, called *Seeds and Fractions*, will be used to describe how mathematics concepts can be constructed during science investigations. As children explore the process of seed germination, data are collected concerning the number of seeds that germinate in each lab group and in each class. Those data can be represented in a variety of ways (graphs, pictures, models, etc.) and used to help the children begin to build an understanding of the concept of fractions. The chapter will culminate with a "whole curriculum" investigation about patterns.

The Shadows Investigation

"Patterns" is a major concept in both mathematics and science. Scientists and mathematicians rely on patterns to make inferences about and provide explanations for phenomena in our world. The *Shadows* learning cycle investigation can be used in a third grade classroom as part of a year-long study of patterns or can be incorporated into a curriculum built around the theme of change. (The final investigation, presented in this chapter is an introduction to the concept of patterns.) In the *Shadows* investigation children are required to utilize mathematical measurements and representations. Those measurements provide the data that will help the children develop the concept; representations (graphs, charts, etc.) of the numerical data can be accessed for further consideration by the students.

The Exploration Phase

The *Shadows* investigation may begin with a teacher-generated question or statement about the changes and patterns that exist in the natural world. The teacher may simply say, "I want you to observe shadows outside the classroom for the next few months." A better lead-in may be an investigation about the nature of shadows which will stimulate student-generated questions about changes in outdoor shadows. Regardless of the context, the teacher uses to segue into the *Shadows* investigation, the children will select one or several objects outdoors and measure the length of the object's shadows three or four different times each day. A four or five day investment in the initial data gathering process will likely be sufficient. The data will be recorded on charts made by each lab group and on a class chart that is kept in full view of all the children in the classroom.

The Conceptual Invention Phase

Once sufficient data have been collected, the class discussion about the data would begin. The purpose of the class discussion is to get the children to negotiate and agree on a common summary of the meaning of their data. In this case, the class summary may be something like: "The shadows got shorter and shorter through the morning and longer and longer after lunch." To add another layer to the analysis, the teacher may wish to ask the children to construct and interpret a bar graph to represent the data. (The graph would consist of the shadow lengths at the time of each observation.) If the children have not done any graphing at this point, this is a very good time to start. The teacher can integrate the graphing concept within the context of the *Shadows* investigation.

The Expansion Phase

Once the class discussion has culminated in the class summary, the teacher has several options. The children can be asked to generate questions that they have about outdoor shadows; each small group can do a different investigation based on the questions asked. The teacher may also choose to tell the children that they will be observing outdoor shadows for the next few months. Long periods of observations of outdoor shadows are probably best conducted using a flag pole or other tall, stationary, nonliving entity. (The teacher would want to ask the children why observing shadows related to a nonliving object would be preferable to watching shadows of a living thing.) Each lab group would be instructed to set up charts to record data about changes in the shadows through the observation period.

Regardless of the question the children start with, the data will soon begin to indicate that the shadows are moving around the base of the flag pole (or object). When the children begin to notice the changing position of the shadow, the teacher can bring the class together for a short discussion of the data. How "far" has the shadow moved? How can we measure the changes in the shadow's position? Is a meterstick useful for measuring changes in the shadow's position around the base of the flag pole? This investigation could ultimately lead to the children's invention of a protractor. The extent to which the children invent a measuring device will probably reflect the time available for the process. If class time is flexible, the teacher could assign the children the task of designing a measuring devise on their own. If time is a limiting factor, the teacher may need to suggest ways the children can measure the changing position of the shadow. A "collar" can be designed to place around the base of the pole (or object). The collar (Figure 20.1) could be constructed from heavy poster board. The diameter of the neck hole of the collar will need to match the diameter of the object that will be measured. In order to make the markings on the collar, the teacher and the children will have to explore a little circle geometry. Those experiences could precede or be embedded within the context of the investigation.

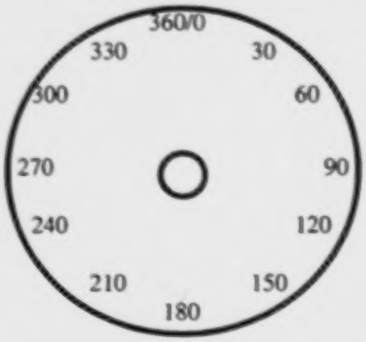

Figure 20.1 *Collar for flagpole*

Teachers often question whether children can learn to use and measure angles before they have had formal classroom instruction about angles. Students can and do think about angles long before teachers introduce terminology and line drawings. The teacher can also consider the differences in "knowing about" and "knowing how." Students can learn how to measure angles prior to learning about angles. More than that, however, the children can begin to construct ideas about angles in the midst of investigations that require the use of angles. Two important aspects about angles might surface during this investigation. First, children will begin to understand that an angle has to do with the space near the point of intersection of two line segments. That is an important part of the angle concept that often eludes high school children who are studying geometry. Second, if the children attempt to redraw in their own journals or charts the angles they measure using the collar around the flag pole, they will quickly see that the size of the angle remains the same regardless of the lengths of the line segments. Again, this aspect of the investigation provides data often ignored in classroom discussions about angles. These data can later be accessed as the teacher assists the children's initial or continuing understandings about the concept of angles. Thus, the investigation may serve to provide children with experiences that will later be built upon when angles are addressed more directly within a purely mathematical context.

The Seeds and Fractions Investigation

The investigation called *Seeds and Fractions* gives the teacher an opportunity to get children thinking about practical applications of fractions while in the midst of exploring seed germination and plant growth. If fractions haven't come up in class discussion yet, then this investigation may suffice to get a dialogue about fractions started. The point of including this investigation in this chapter is to show how scientific inquiries can serve as representational contexts in which children can begin thinking about mathematics concepts. The science data will not be sufficient to provide the children with a broad base concerning fractions, but those data will likely get the children thinking about fractions from a utilitarian point of view. The teacher would follow this investigation with additional opportunities for children to discuss and think about fractions. (See Ball, 1993, for an excellent narrative on thinking about teaching fractions.) An expanded description of the learning cycle investigation follows.

The Exploration Phase

The children begin *Seeds and Fractions* by preparing several seeds for germination. The teacher has to decide whether each group of children will plant the same number of seeds or whether the number of seeds selected will be left to the children's discretion. There are advantages and disadvantages each way. If the teacher decides how many seeds each group will start with (e.g., 10), then the children will have a common reference for the fractions generated later. On the other hand if the children are allowed to select their own number of seeds, the class will not have a common reference point, but the teacher will be able to pose the question, "Which group germinated the most seeds?" If each group did not start with the same number of seeds, a need will exist to develop a strategy to resolve the issues of greater than and less than. The dilemma will be solved differently in different classrooms.

The germination chambers are easy to make. Each group uses a zip-type sandwich baggie and a damp (not wet) paper towel. The seeds are placed on the paper towel and then put in the baggie. The children observe the seeds over a period of several days. Many observations and measurements can be recorded: changes in the appearance of the seeds, changes in the size of the seeds, changes in the lengths of the germinating parts of the seeds. The seeds should be removed from the baggie at the first sign of mold, especially if the intent is to follow the seeds through complete life cycles.

The Conceptual Invention Phase

The class discussion will occur when all the seeds have germinated or when ungerminated seeds appear unlikely to germinate. A data chart for the class data can be placed on a large poster or on an overhead transparency. The discussion will focus on the events in the baggies. The teacher or a child in the class will record the children's observations as the discussion progresses. The idea to be invented here is about sprouting or germinating. The children will be asked to describe what happened to the seeds in the baggie. Comments like "the seeds swelled up," "little things started coming out of the seeds," and the parts coming out of the seeds had little leaves" would be expected. Once all the data have been placed before the class, the teacher can ask the children to summarize what the class found out. The exact summary depends on the children and their observations, but the statement should include a reference to the seed, moisture, and the parts of a new plant coming out of the seed. Before labeling the process as germination or sprouting, the teacher will ask the children if they know what the process is called. Both terms—germinating and sprouting—are acceptable and it is appropriate to let the children know both terms are used. If the children do not know what the process is called, the teacher can give the labels and write them out on the board.

The Expansion Phase

After the class discussion, the teacher again has several options. One suggested activity is that the children be asked to decide which group had more seeds germinate. A data table would be placed on a chart or overhead transparency and the children would be asked to record the number of seeds they started with and the number of seeds that germinated. (The order of the headings of the table has been purposefully constructed to encourage the children to consider the number of seeds that germinated in light of the number of seeds they placed in the baggie.)

Lab group	How many seeds germinated?	How many seeds were in the baggie?

If the groups did not begin with the same number of seeds, there will be a good discussion about how to determine what "more" means. In this case, fractions can be used to help better understand what it means to have "more" if one group started with 10 seeds and 5 of those germinated while another group started with 9 seeds and 5 of those germinated or if a group that started with 12 seeds saw 6 of those seeds germinate. This investigation is not intended to replace other manipulative activities dealing with fractions. In fact, the teacher could break up the discussion with other strategies. For example, the children could be asked to use different representations to tell about the number of seeds that germinated, e.g., drawing pictures of the seeds in the baggie and coloring in the ones that germinated. As Ball (1993) suggests, children need opportunities to draw out and fill in their own representations of fractions. If this investigation occurs early in the year, the children can use data gathered from planting the seeds to generate further tables of data for contemplation with regard to fractions (i.e., the fraction of seeds that actually grow into plants, the fraction of seeds planted that complete their life cycle).

From the perspective of the science teacher, another expansion investigation for this learning cycle would be to allow the children to plant their seeds and then spend the ensuing weeks tending the plants, making observations about the growth of the plants, and collecting and recording data about the growth of the plants. The data collected can be organized on charts and displayed in the classroom for continual viewing by all the students. Analysis of the data via other representations (e.g., bar graphs) would further supplement the science inquiry with mathematics content.

Patterns: Integrating Across the Curriculum

To conclude this chapter, a cross-disciplinary investigation on patterns is described. The investigation titled, *You Can Count On It!* has been designed to assist children in their early development of the concept of patterns. Patterns are essential in understanding mathematics and science concepts, but patterns are also an everyday part of our everyday world. Recognizing and generating patterns are important processes in science and in daily living. Having an idea about patterns allows the child to make better sense of occurrences; seeing patterns makes classifying, problem solving, and predicting more successful (and more fun). This investigation has the potential to integrate science, mathematics, social studies, language arts, physical education, music, drama, dance, and art curricula.

The Exploration Phase

The exploration includes three separate inquiries: recording and analyzing the events of daily schedules for three days, examining the sequence of two strings of beads prepared by the teacher, and reading and discussing *The Three Little Pigs* book.

1. The teacher will prepare a chart on which each child can record each day's events for three sequential school days. The children will be instructed to keep a fairly detailed record of the events in their days. The teacher might start the process by asking the children to tell about the things they do after they get up in the morning and before they go to bed each night. The word "pattern" should not be used at this time. The children will be responsible for keeping the logs of their time for the three-day time period. In the meantime, the other two parts of the exploration can be started. Once the schedules have been generated, the children will be asked to tell about their schedules. The observations will be written on a chart titled "Our Schedules." The chart will be displayed for all the children to see.
2. The teacher will create patterns using strings of beads. Two different strings will be made for each group of students, but all the groups should have the same two strings of beads. Wood or glass beads can be used to create two very different patterns. One pattern should be fairly easy to discern (e.g., 2 blue, 1 green, 2 blue, 1 green, etc.). The second string should be a little more difficult (e.g., 2 blue, 1 green, 2 red, 1 green, 2 blue, 1 green, 2 red, 1 green, etc.). After the children have drawn and described their bead strings, the teacher will ask for reports about their observations.

The observations will be recorded on chart paper titled "The Beads" and displayed near the "Our Schedules" chart. The idea of patterns will not be discussed yet.

3. The teacher will make copies of *The Three Little Pigs* available for the children to read. Reading circles (or whatever system is generally used) can be utilized to facilitate a discussion about the behaviors of the wolf and the pigs. The teacher records the children's observations on a chart titled "The Three Pigs." The chart will be displayed with the first two charts for all the children to see. (Note: Although alternate versions of the story exist, it is best at this time to stay with the original story for the purpose of data collection for this part of the investigation. To further integrate the investigation with language arts and social studies, the teacher may choose to have the children later read an alternative version of the story (i.e., from the wolf's perspective to stimulate a discussion about stereotypes and prejudice.)

The Conceptual Invention Phase

The notion of patterns will be developed through a class discussion of the data the children have collected about their schedules, the beads, and the story. The teacher may begin the discussion by asking the children if they want to add to the charts they made earlier. All comments are recorded. The children will then be asked to think about how the different situations were alike; comments will be recorded on another chart. The result of the discussion will be that the children will begin to think about regularities in their schedules, the bead sequences, and activities of the wolf and the pigs. It is the children's responsibility to generate the notion of the regularity of the events. They will have their own words (happened over and over again, happened at the same time, happened in the same order).

When the teacher believes the idea of pattern has been verbalized and agreed on by the class, she will ask the children if they know what these regularities in events are called. In the discussion, children might use several words like routine, schedule, and pattern. The rule for determining whether a term will be accepted or not is that it has to fit all the data the children have collected. The children will need to evaluate each word suggested by classmates. For example, the schedule and the *Three Little Pigs* story could be thought of as showing "routines," but the beads could not be described as having a routine.

The children will be asked to make a sentence (concept statement) to summarize what they have learned about patterns. The teacher can start this part of the discussion by writing "Patterns..." on the board or on a piece of chart paper. The children will work together to devise a statement that tells what they have learned about patterns. The final statement will be written on a piece of chart paper and displayed in the classroom. The sentence will be similar to the following example: A pattern happens when numbers or events or properties are repeated regularly. Patterns are something you can count on. We can find patterns everywhere in our world.

It may be important to note that the examples of patterns the children investigate are not "perfect" patterns. The pattern in the daily schedule is likely broken on weekends, holidays, and days a child is ill. The story about the three pigs also contains variations in the patterns of behavior. The teacher may wish to address these instances directly by asking the children (at the conclusion of the invention discussion) when a pattern is not a pattern. More specifically, the teacher may ask the children to identify the aspects of their daily schedule and the three pigs story that *do not* represent patterns.

The Expansion Phase

The children will expand on their understanding of patterns by engaging in several activities that will encourage the application of the concept and the generalizability of the concept to other content areas and life experiences.

1. The children will work in small groups to list other patterns they think occur in their daily lives. Once the groups have generated lists of patterns, a class discussion will be held to allow the children to share their patterns and evaluate the patterns other groups have listed. During the discussion, the teacher may wish to encourage the children to think specifically about the important role patterns play in science and mathematics. The relationship among patterns and mathematics and science can be continually reexamined as the school year progresses. The class may choose to keep a chart in the classroom to record instances where they see the relationship at work.
2. Recognizing patterns is important, but being able to generate patterns will take the children's learning a little further. The children should have opportunities to engage in both recognizing and generating patterns. Pattern blocks can be used to allow the children to generate their own patterns. Each group of children will use the pattern blocks to design a pattern that another group will try to figure out. Once the groups have completed their patterns, the children will trade the patterns with another group. Each group will then attempt to decode and describe the pattern they have been given. A little different twist can be placed on the activity if the children trying to figure out a pattern made by another group are asked to slightly change the pattern they were given and see if the group making the original pattern can discern the new pattern.

   The art curriculum can be further integrated at this point in the investigation as the children can be asked to draw, sculpt, or produce textured designs to represent patterns of their own making. Those works can then be displayed in the classroom and around the school building.
3. The finale for the investigation is a cross-school investigation of the concept of patterns. Suggestions, not specifics, are given here; each school environment has differing potential for integration across the curriculum. The following list has been generated through the efforts of teachers who have participated in developing and integrating this learning cycle. The extent to which integration can occur is seemingly unlimited!

Music:	rhythm, verse/chorus, repeating measures
Poetry:	rhyming patterns
Mathematics:	number sequences, geometric patterns
Science:	snakeskin patterns, life cycles
Dance:	folk dance and square dance patterns
Physical education:	kickball, baseball, football (any sport)
Architecture:	building styles of different Native American cultures (e.g., plains vs. coastal groups), historically important European architecture (e.g., Baroque, Renaissance, etc.), house roof styles in different parts of the United States

Concluding Thoughts

An integrated science and mathematics curriculum has the potential to provide complex, contextual opportunities for child explorations and can ultimately help build a broader base for the development of "essential" concepts in mathematics and science. The degree to which the curriculum is integrated will depend on the teacher's philosophy of teaching and learning and the investment she is willing to make in the process. The title of this chapter suggests that content is more often coordinated than integrated. Indeed, current models tend to promote integration of mathematics and science content primarily at a skills and coordination level. Lonning and DeFranco (1994) report that graphing appears to be the way most publishers attempt to integrate mathematics with science (and other disciplines). Obviously the links between mathematics and science go well beyond that narrow focus. The cognitive connections among mathematics and science content are almost limitless. Teachers who successfully integrate mathematics and science are generally those who view mathematics as something more than tools and skills and who believe science is more than a set of facts. Curricula that effectively integrate mathematics and science content will be generated by developers who understand that mathematics and science are—at their cores—process-oriented fields of inquiry. The investigative processes (observing, pattern finding, hypothesizing, evaluating, inferring, etc.) of science are available to the mathematician and the conceptual processes and tools of mathematics are at the fingertips of the scientist. As children have opportunities to develop their understandings of mathematics and science in integrated environments, we can anticipate a generation of youth who see beyond schooling's traditional, compartmentalized notions of science and mathematics and subsequently develop a more stable, "big picture" view of those disciplines.

The advantages of curricular integration reach beyond the student, however. Teachers who utilize the connections between and the processes inherent in the disciplines of mathematics and science can reap professional and personal benefits as well. Instructional time is more effectively used in a classroom where the connections between content areas are captured and built upon. Transition time—especially that associated with start up and clean up—is held to a minimum when the focus of instruction shifts from discipline-specific content to a more integrated view. In many K-3 classrooms, science and mathematics instruction may take a "back seat" to the objectives of the language arts curriculum. If science and mathematics content are viewed as intimate partners, both areas of study will experience increased time and focus in the classroom. Integration, then, is a worthy ally for the teacher who desires to provide a well-rounded intellectual environment while still addressing the "basics." Planning, paper grading, and preparation can also be reduced by integrating the day-to-day instruction of science and mathematics. If those disciplines are further integrated with the language arts and/or social studies curricula, the teacher may save countless hours of extraneous planning and preparation. Granted, a certain amount of start up time is needed when we make a professional decision to change what we do in the classroom. That time, however, will be an investment in the cognitive and conceptual development of the children and of our own understandings of mathematics and science content.

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Chapter 21

Integration of Mathematics and Science in Food and Energy

Anita Roychoudhury & Iris DeLoach Johnson

Integration of mathematics and science has been a repeated theme of recommendations made by both mathematics and science educators (Berlin & White, 1994; National Council of Teachers of Mathematics, 1989, p. 20, 1995; National Research Council, 1996, p. 213; Rutherford & Ahlgren, 1990). Common skills for both subjects include classifying, collecting and organizing data, communicating, controlling variables, problem solving, developing models, graphing, inferring, and measuring (Benham, Hosticka, Payne, & Yeotis, 1982). As the framework for combining lessons in both subjects, these common skills can help to enhance child understanding, relate school learning to real-life events, raise child curiosity, develop positive student attitudes, and facilitate time management for teachers (Boidy & Moran, 1994; New, 1990; Ohio Department of Education, 1991; Phillips, 1993).

In this chapter, we provide caveats for integrating mathematics and science lessons, present some general guidelines for developing lessons that combine topics from mathematics and science, and provide some examples of integrated lessons that are appropriate for early childhood education. Mathematical and scientific skills the lessons utilize are presented in Table 21.1.

Skills	**Math Les.**	**Sci. Les.**	**Math Les.**	**Sci. Les.**	**Math Les.**	**Sci. Les.**	**Math Les.**	**Sci. Les.**
Applying		x		x		x		x
Building number sense	x		x		x		x	x
Collecting, recording, and interpreting data	x	x	x	x	x	x	x	x
Communicating	x	x	x	x	x	x	x	x
Comparing	x	x	x	x	x	x	x	x
Estimating	x		x		x		x	x
Exploring informal geometry concepts	x						x	x
Finding patterns	x	x	x	x	x	x	x	x
Observing		x		x		x	x	
Performing whole number operations	x		x		x			x
Problem-solving	x	x	x	x	x	x	x	x
Reasoning	x	x	x	x	x	x	x	x

Table 21.1 *Science process and mathematics skills used in Lessons 1, 2, 3 and 4*

Initial Caveats

Integration of subjects has been criticized for limited scope (Lonning & DeFranco, 1994), its placebo effect in making integration appear to be a solution to a teacher's overloaded workday (Hughes, 1993), and the tendency to inappropriately apply integration merely for the sake of integration (Brophy & Alleman, 1991). Generally, these criticisms can be accredited to integrating topics without regard to specific educational goals, or nullifying goals for one subject in favor of another (Brophy & Alleman, 1991). The following initial caveats should help to avoid these criticisms when integrating mathematics and science.

1. Consider the curriculum needs of both subjects so that one does not become secondary to the other. Consult the graded course of study for each subject to locate objectives appropriate for both subjects.
2. Allow adequate time for children to experience and complete each activity as well as to bring closure to each lesson; otherwise, the activities tend to appear as mere busywork or isolated experiences which obscure the benefits of integration.
3. Include basic skill development and production of a specific item by the children. The inherent satisfaction in producing a concrete item can better motivate children toward learning.
4. Emphasize active child involvement in learning concepts. The teacher should be involved as a facilitator of learning rather than a director of learning.
5. Keep specific educational goals in mind as activities are planned. Instruction should be developmentally appropriate; should provide for learning by inquiry; and should enable children to continually approach problems, form and apply concepts related to those problems, then reflect on their learning to learn even more (Hughes, 1993).

Having acknowledged these initial caveats, the authors offer the following general instructional guidelines for integration of mathematics and science:

General Instructional Guidelines

1. Examine topics to be covered in both subjects during the school year to coordinate the sequencing of topics from both subjects when possible. However, consider the background knowledge and skills required for a topic before changing the sequence of presentation merely to facilitate integration.
2. Select topics from both subjects that appear to have "overlapping skills, concepts, and/*or* attitudes" (Fogarty, 1991, p. 76). Topics that have little or nothing in common probably should not be taught using an integrated approach. A general rule to follow is: If it doesn't fit, don't force it!
3. Explore the children's ideas related to the topic to connect the activities to their interests. Include current situations in the school, community, state, or nation as they might relate to the topic (Clayton, 1991).
4. Determine the prior knowledge and beliefs children have about a topic before beginning instruction (Osborne & Freyberg, 1985; Roth, 1991). For example, in a class brainstorming session the teacher may use a webbing strategy (Phillips, 1993), or use a "know, want to know, and learned" (KWL) strategy (Ogle, 1986; Tompkins & Hoskisson, 1995). The responses during the brainstorming session will help the teacher identify appropriate activities designed to dispel many of the erroneous notions the children may have.
5. Use science activities as concrete examples of mathematical principles (e.g., patterns in nature, ordering of events in a growth cycle, and geometric shapes in nature); conversely, help children draw mathematical generalizations from science activities (e.g., combining two quantities results in a new (usually greater) quantity; separat-

ing an item into halves results in two smaller pieces of identical shape (generally) and size, and many three-dimensional objects are made of two-dimensional shapes).

6. Plan developmentally appropriate activities. Consider how the children think; what their current understandings are about such concepts as time, cause-and-effect, space, and number; the length of their attention spans; and their needs for physical movement and visual cues (Crawford, Gums, Nelson, & Neys, 1994; Smith, 1982). Remember the early childhood student is more likely to be preoperational in thinking, and thus, will need multiple experiences and observations of the same concept, to assist in moving toward operational thought (Benham, Hosticka, Payne, Yeotis, 1982).
7. Introduce concepts by providing a sequence of experiences that lead the children to discover the desired content. Also use probing questions and periodically ask children to justify their responses. The teacher may be surprised to discover that correct answers may be given based upon invalid reasoning.

Integrating Science and Mathematics: Lessons on Food and Energy

The lessons in this chapter may be used to combine common skills, concepts, and attitudes as they relate to energy, foods, health, or nutrition. In early childhood classrooms such topics are preferably taught within thematic units (Phillips, 1993). The lessons in this chapter serve as examples of integration of mathematics and science either apart from thematic units, or within such thematic units as The Farm, The Garden, Harvest Time, National Health Month, or National Nutrition Month.

The first three lessons focus on analysis of foods: food groups, meals, and Calories. [Note: The lesson on Calories is considered more appropriate for the upper grades in the early childhood curriculum. Furthermore, the teacher should decide whether to use a capital C (i.e., food Calorie), or a small c (i.e., kilocalorie or calorie) when spelling CALORIE. See lesson 3 for more details.] The fourth lesson highlights food as a source of energy for the human body compared to winding as a source of energy for a wind-up toy. Each of these lessons builds connections to the common idea that eating healthy food provides the body with energy. Each lesson plan has two main parts: general notions and specific notions. The general notions are (a) lesson objectives for the learners (NCTM, 1989; Ohio Department of Education, 1989), (b) content that the teacher should know and select portions thereof for the children to discover, (c) science processes and mathematical skills, and (d) materials. The specific notions are (a) invoking prior knowledge, (b) exploration, (c) concept introduction, (d) concept application, (e) closure, and (f) auxiliary activities.

Lesson 1: Food Groups

Objectives

The children will...

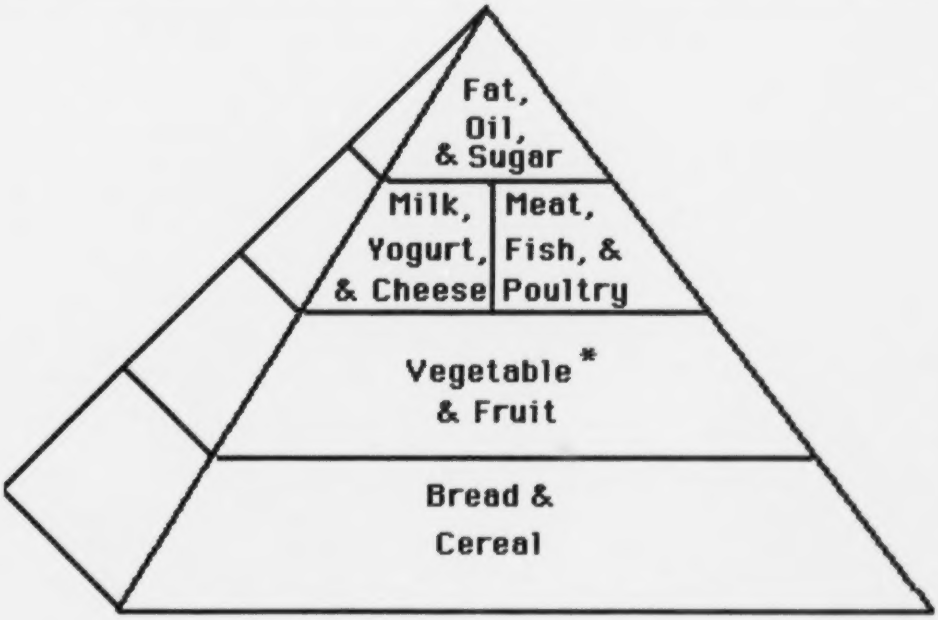
1. identify, compare, and classify familiar foods.
2. describe the main food groups and use that description to make a table, floor/table graph, simple picture graph, or bar graph to sort a selection of foods.
3. develop the concept of addition while counting foods, including joining, separating, ordering, and comparing sets of foods counted.
4. compare numbers of food in two or more sets and identify whether a collection of food items is less than, the same as, or more than a given number of food items, both when the objects are arranged in a pattern and when they are randomly placed.

5. count foods using a 1-1 correspondence and using skip counting by twos, threes, and fives.
6. learn strategies for addition of whole numbers such as counting all; counting on; one more, one less; two more, two less; doubles; doubles plus or minus one; and doubles plus or minus two; make ten; and using ten frames.
7. use and understand the language of logic in talking about problem situations and solutions to problems.
8. use the symbols $<$, $>$, $\leq$, $\geq$, and $=$ in describing order as well as the terms "at least" and "at most" [grades 2-3 only].

Content

The United States Department of Agriculture (USDA) and the Department of Health and Human Services (DHHS) classifies foods into food groups based upon the nutrients (i.e., vitamins, minerals, proteins, carbohydrates, and fats) they provide (USDA, 1992). The basic food groups are (a) bread, cereal, rice, and pasta (hereafter referred to as bread and cereal); (b) vegetables; (c) fruit; (d) meat, poultry, fish, dry beans, and nuts (hereafter referred to as meat, poultry, and fish); (e) milk, yogurt, and cheese; and (f) fats, oils, and sugars (Figure 21.1).

For children in kindergarten-grade 1, the teacher may be tempted to present the vegetables and fruit food groups combined. However, Herr and Morse (1982) warn that doing so requires



* In the USDA leaflet, vegetable and fruit are categorized separately.

Figure 21.1 *The food guide pyramid*

young children to categorize many dissimilar objects into one category, which is not a developmentally appropriate practice. Children in this age group may be told that since our bodies need such small amounts of fats, oils, and sugars, this lesson will focus on the other food groups. However, the children should be made aware when foods from other food groups contain significant portions of fats, oils, and sugars. For example, bacon in the meat group usually contains a significant amount of fat.

Plants and animals provide our food. We may get our food from the store, but before the store received the food, the farmers grew the plants, raised the animals, then processed them in such a way that we could get them from the store. There are many different kinds, colors, and shapes of food. Some of them look, feel, smell, and taste the same; some are different. We may simply wash some foods and eat them raw (by biting or slicing); other we cook, can, freeze, or dry. Although most members of the meat, fish, and poultry group come from animals, nuts and beans in this food group come from plants. Foods that come from plants may come from different parts of a plant: flower, fruit, leaf, root, seed, or stem. The part of a plant that contains seeds is the fruit of the plant. Thus such foods as cucumbers, eggplants, peppers, pumpkins, and squash are fruit (Hausherr, 1994). Many of the foods we eat are good for our bodies. They help us feel healthy, grow, and have energy. Some foods we eat are not good for our bodies. They help cause tooth decay, diseases, and other medical problems.

Materials

1. Real food (from the homes of the teacher and children), plastic models of food (from the housekeeping center in the kindergarten-grade 1 classroom), and pictures of foods (from magazines and newspaper sales ads) representative of the food groups.
2. Sentence strips cut into 8"-10" pieces.
3. Felt markers, crayons, scissors, glue, paste, tape.
4. 12" x 18" construction paper and chart paper
5. Student writing paper.
6. Unifix cubes, or other manipulatives for counting.
7. Large paper bag or large plastic bag [optional].
8. Blindfold [optional].

Additional materials for children, grades 2-3:

9. Pictures of various common foods on index cards. Each food card is half of a 3" x 5" index card with a picture of a food on it. These foods should represent each of the food groups.
10. Standing pyramid made of poster board (large version) or card stock (smaller version) showing the main food groups (Figure 21.2). The large pyramid may be placed in a strategic location in the classroom for all children to see, or the smaller model may be duplicated and placed on individual student desks or tables where children work in cooperative groups.
11. A rectangular sheet of paper for each child or group of children when working cooperatively. This sheet should be divided into five equal parts, with one or two ten-frames drawn in each part. A ten-frame is 2 x 5 or 5 x 2 grid often used for helping children capitalize on using the numbers five and ten as anchors when counting (Van de Walle & Watkins, 1993). The ten-frames should have grids large enough to accommodate the size of unifix cubes, or other counters.

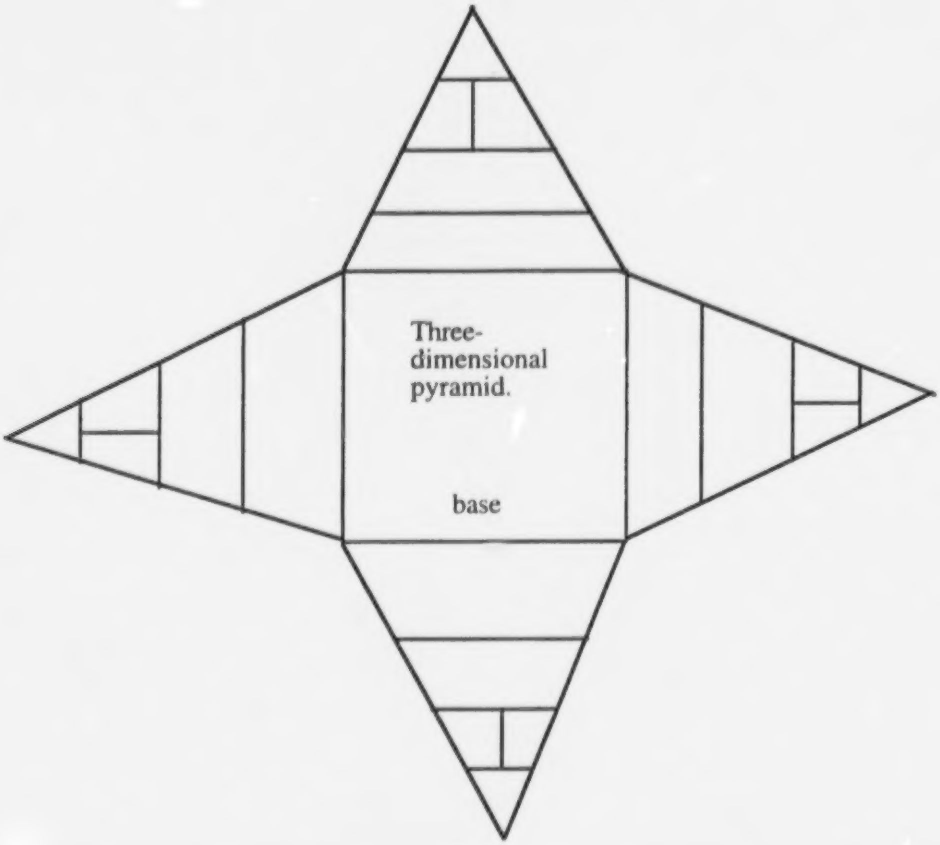


Figure 21.2 *Cut-out Pattern for Large Standing Food Pyramid*

12. Small regular-sized envelope to hold food cards.
13. Large pictures of foods mounted on construction paper to be used in class demonstrations, especially when real foods isn't available.
14. A large poster depicting the Food Guide Pyramid (USDA, 1992) with number of servings shown.

Invoking Prior Knowledge

With a rhyme, song, finger play, or short story (Crawford, Gums, Nelson, & Neys, 1994) the teacher should introduce the idea of eating properly, or eating foods from the food groups. Although the teacher may sometimes create the rhyme, song, play, or story, the list of Children's Books provided in Appendix A may be helpful. Ask the children to tell what they know about eating properly. In so doing, help children generate a list of words naming and describing foods. Write these words on chart paper or on pieces of sentence strips.

For children in grades 2-3, the teacher may choose to start the lesson by announcing the topic and encouraging children to brainstorm about the things they KNOW about foods, and the things they WANT TO KNOW about foods (Tompkins & Hoskisson, 1995). The responses may be recorded on a KWL chart (Figure 21.3).

FOODS

K	W	L
WE KNOW. . .	WE WANT TO KNOW. . .	WE LEARNED. . .

Figure 21.3 *K-W-L Chart*

Exploration

For children in kindergarten-grade 1, the teacher should distribute foods to children for free exploration. Presenting a food group per day (or 2-4 days) would be preferable; however, the teacher may choose the less expensive option of distributing samples of food from various food groups over a shorter time period. During exploration the teacher may expect some children to peel, slice, taste, smell, and even play with the foods given to them.

For grades 2-3, the children should consult the information shared during the KWL brainstorming session, then take an envelope of food picture cards and sort the cards into child-chosen categories. Although the children may initially sort the food cards according to the color, size, or shape of the foods, eventually they can be expected to sort according to food groups. Later, if time permits, the children may also sort the foods based upon how the foods were prepared before eating (raw, cooked, dried, frozen, or canned), or based upon the food source as a plant or an animal.

Following each sort the children should count the foods in each category, and record the count per category as well as the total. A drawing and written description of how the count was obtained may also be provided. For example, if 38 food cards were counted, the child may indicate the count as seven groups of 5 with 3 singles, or three groups of 10 plus 5 singles. The drawings and written descriptions may be evaluated after the children have revisited these papers during the concept application or closure phases of the lesson.

With a rhyme, song, finger play, or short story the teacher may introduce the new food group for the day. Afterwards, the teacher may select foods representative of each food group to be discovered and guide the children through a "getting-to-know-this-food" party. For example, given a food that is a bread the teacher may distribute pieces of bread, have the children taste it, and discuss what they've discovered. If the lesson is preceded by, or included in, a thematic unit on farms, gardens, or plants, picture cards showing the growth sequence of the food may also be shared to assist children in identifying which part of a plant (or animal) the food represents.

The teacher may use large pictures of food, real food samples, the Food Guide Pyramid on a large poster or a three-dimensional models (see Figure 3) to introduce the foods from the various food groups and to facilitate questions such as: What do we use this food for? Where do you think this food comes from? Have you eaten this food before? How many of you have eaten this food before? Do you like the appearance and/or taste of this food? Why or why not? How many of you like the taste of this food? Why or why not? Do you think this food is good for us to eat? Why or why not?

The teacher may record the children's responses on chart paper in tables, picture graphs, and/or bar graphs. Additional questions focusing on mathematical concepts might include: How many more of us had eaten an apple before than those who had eaten a pineapple before? Which fruit was the favorite for more people in this class? If one more (or two more) people liked pineapple how would that change our data? If we doubled the number of people who have eaten blueberries before, what number would we record in the table? If you were going to tell our principal about the number of people in our class who like blueberries, what would you say? Alternatively, the teacher may follow the free exploration by returning to the KWL chart, if done previously.

As a food is introduced, a unifix cube or other manipulative may be added to a stack to keep a count of the number of foods introduced. Periodically the teacher may encourage the children to offer word and number sentences to summarize their current findings. For example, "We have tasted two breads and three cereals so far. We have more cereals than we have breads, because three is more than two." Children in grades 2-3 may also record this information using symbols: 3>2. "We have one more cereal than we have bread, because 3-2=1 (counting backward), or 2+1=3 (counting on). We have five foods in the bread and cereal food group, because 3+2=5."

In kindergarten-grade 3, the children should also be asked to describe characteristics of foods in the food groups that make those foods distinguishable from foods in the other food groups. The teacher should encourage the use of the informal language of logic in describing the reasoning the children used in making their classifications. Examples are as follows: *If* the food is green, *then* I think it is a fruit or vegetable. *Since* the edible parts of these plants grow in the ground, these vegetables are roots. I believe these are fruits *because* they have seeds. *Not all* vegetables are green and yellow. *Some* breads and cereals are made from wheat.

Concept Application

The children should consult the daily lunch menu to identify the foods representative of the food group(s) being studied.

Working in groups of 4-8, the children in kindergarten-grade 1 may take turns sorting the foods in the housekeeping center into two groups: *examples* of today's food group and *nonexamples* of today's food group. Children should provide informal explanations for the decisions used to place a food in the *example* or *nonexample* pile.

The children in grades 2-3 should update their previous sorts and report their results. Use ten-frames or other devices to assist in number sense (Van de Walle & Watkins, 1993). For example, the child who has seven breads may note that seven is "five plus two," "double two plus three," "four plus three," or "three less than ten." If more than 10 food cards are counted, the children should form a group of 10 food cards plus the number remaining, and discuss the place value of each digit in the numeral representing the count.

Closure

The children may make a picture book or mobile depicting some of their favorite foods in each food group, or have a "cooking" party. If the expense isn't too prohibitive, the children may help the teacher cook on the last day for each food group or on the final day when all food groups have been presented. For example, the class may make fruit salad, vegetable stew, various breads, spaghetti, or fruit-filled milk shakes. [Warning! Be sure to consult parents for possible food allergies.]

In kindergarten-grade 1, the teacher should help the children summarize what they've learned and write this information as sentences on chart paper. The main points may be further summarized and coordinated with the music of a familiar song. Groups of children may take turns leading or acting out key elements of the song. First graders may also select at least one sentence from the chart paper to write in their class journals or in their picture books accompanied by a drawing of their favorite food.

Children in grades 2-3 may glue their small picture cards to a large triangle (cut from construction paper) to represent the Food Guide Pyramid. The teacher may use these Food Guide Pyramids to decorate the classroom walls for a couple of weeks, then encourage children to take them home to post in their bedrooms, or in their kitchens. As an alternative, the children may work in groups of four to select one or two favorite food cards per food group, then tape those to the sides of the large solid pyramid made for the class. The large poster of The Food Guide Pyramid may also be used for review during regular intervals throughout the school year as a part of the daily early morning calendar activities often done in early childhood classrooms. For example, after asking the usual early-morning questions: "How many days have we been in school? Is today a rainy day, cloudy day, or sunny day?" ask questions like, "How many people had a serving from the fruit food group for breakfast this morning? Name the fruit."

Auxiliary Activities

1. The children may choose to role-play as a favorite food on the "Food-Group-of-the-Day" day. For example, if a child chooses grapes during the Fruit-of-the-Day day, that child may dress in clothing that is the same color as his/her favorite type of grapes. The child may also wear a "breastplate" made of a large paper bag, construction paper, or plastic bag decorated with circles (two-dimensional geometric shapes) to represent grapes, and hung around the neck with a string of yarn. The children may also make a model of the food in paper mache or clay and describe the three-dimensional geometric shapes used.
2. The children may draw a picture of their favorite food in the food group being studied, then hide the picture while they give clues to their classmates, and wait for them to guess what the food is. The problem solving, reasoning, and communication in this activity represent both science processes and mathematics skills.
3. The children may experiment with the affect of sight and smell on the children's food choices. For example, after giving the children blindfolds and telling them to hold their noses, have them taste small pieces of potato, followed by small pieces of apple. See if they can tell the difference between the two foods. You may graph the results showing how many children preferred the potato to the apple. As you continue the experiment with other children in the class, change the order the foods are tasted: potato first sometimes, apple first other times. Try other foods that have similar textures so it won't be easy to guess what the foods are. This activity emphasizes observing; gathering, recording, and displaying data; comparing; and inferring.
4. The children may make a picture book dictionary of foods to represent all of the food groups, or a selected food group. For example, a child may represent one food per alphabet (regardless of food group), then indicate which food group is represented, or a breads and cereals picture book could be made. Each page may also include a story problem or number sentence.
5. The children may use picture cards or drawings to order events based on time in the growth and production cycles of foods. Sequencing is both a mathematics skill and a science process.

6. The children may pull numeral cards from a deck, count the appropriate quantity of a given food, then draw a diagram of their results on paper. For example, the child who pulls the 4 card should count four apples from a pile of apples, draw four apples on a sheet of paper, then write the numeral 4 below the drawing. As an additional science option, the children may include the name of the food group on the same sheet.
7. The children should be asked to estimate the number of a given quantity of food, then explain the reasoning for their estimate (e.g., "I think there are eight because it looks like there are more than the number of fingers on my right hand.") Afterwards, the children may use ten-frames or other devices to arrange the foods in groups to discover the actual count. The actual count should be compared to the estimate avoiding references to good, bad, right, or wrong estimates, but instead referring to "close" and "not so close" estimates.
8. The children may describe the three-dimensional Food Guide Pyramid from different perspectives [grades 2-3].

Lesson 2: Meals

Objectives

The children will...

1. identify foods that might be eaten at each meal: breakfast, lunch, dinner.
2. tell whether a collection of food items is less than, the same as, or more than a given number of food items, both when the objects are arranged in a pattern and when they are randomly placed.
3. develop the concept of addition while counting foods, including joining, separating, ordering, and comparing sets of foods counted.
4. learn strategies for addition of whole numbers such as counting all; counting on; one more, one less; two more, two less; doubles; doubles plus or minus one; and doubles plus or minus two; make ten; and using ten frames.
5. explore capacity using cups and mass using non-standard units (i.e., modeling clay forms representing 2-3 ounces) and recognize these measuring units [grades 2-3].
6. collect data and record by tallying [grades 2-3].
7. explain in words why a solution is correct [grades 2-3].
8. use food cut into fractional amounts (halves, thirds, fourths, sixths) to investigate different physical representations for the same fractional parts of whole objects or sets of objects [grades 2-3].
9. use the symbols $<$, $>$, $\leq$, $\geq$, and $=$ in describing order as well as the terms "at least" and "at most" [grades 2-3].

Content

The human body needs nutrients such as proteins, carbohydrates, fats, oils, minerals, vitamins, and water to function properly. These nutrients are obtained from the foods we eat in meals and snacks. Thus it is important to eat a variety of foods as well as at least one food from each of the food groups in each meal. This lesson focuses on the foods eaten during meals: breakfast, lunch, and dinner.

Although geographic location, family income, and tradition often influence what people eat during meals, there are dietary guidelines for all Americans (USDA, 1995). These guidelines include recommendations for eating a variety of foods, choosing a diet with plenty of foods from the lower two levels of The Food Guide Pyramid (USDA, 1992), and choosing a diet with few foods from the highest level of The Food Guide Pyramid. The Food Guide Pyramid also contains the number of recommended daily servings of each food group. The number of recommended servings for primary school children are shown in Appendix B.

Children in kindergarten-grade 1 should seldom, if ever, be required to count daily servings as recommended by the USDA (1992), but should be encouraged simply to eat a *something* from each food group for each meal. For children in grades 2-3, a discussion of serving sizes can be tied to the physical characteristics of the foods involved. For example, it is more appropriate to get a slice of bread, because it generally comes in slices; half of a bagel, because a bagel isn't necessarily packaged in slices; and a cup of milk, because it is a liquid. More detailed information about serving sizes and recommended daily servings can be found in Appendix B.

Materials

1. Place settings with plastic or paper-drawn utensils; paper plates may be used or circles may be cut from colored construction paper or cardstock.
2. Containers to represent cups (i.e., full cups, half-cups, third-cups, and three-fourth-cups), ounces (dry and liquid), and tablespoons.
3. Plastic models of food, magazine/newspaper pictures of food, and modeling clay representing 1 1/2 oz., 2 oz., and 3 oz. portions of cheese and/or meats
4. Glue, paste, tape, markers, crayons
5. Chart paper
6. 8"-10" pieces of sentence strips
7. Pictures of model meals (healthy and less healthy)

Invoking Prior Knowledge

With children seated in a circle, the teacher may read a poem or story, or sing a song about meals: breakfast, lunch, and/or dinner. Identifying breakfast as the food eaten in the morning, the teacher may ask the children to think about the foods they ate for breakfast. The teacher may write on chart paper the names of the foods eaten; however, writing the food names on 10-inch sentence strips will facilitate sorting according to food groups later. The teacher may provide a chart or have the children prepare a table/floor graph divided into five or six rows (representing the food groups).

The children may take turns moving the food names from the list of breakfast foods into the columns representing the appropriate food groups. During this part of the exercise the teacher should be prepared to help children discover ways to fill in the graph for foods that are comprised of more than one food group (e.g., grilled cheese sandwich or bacon-egg-and-cheese croissant/biscuit).

For children in grades 2-3, the poem, story, or play may be omitted in the early part of the lesson and used during the concept introduction.

Exploration

Children in kindergarten-grade 1 may explore "preparing" healthy breakfast meals while in the housekeeping center. Plastic models of foods should be used when possible; pictures may be used, if necessary. Pictures may also be used as a follow-up to the use of models. As the children present their healthy breakfast, the teacher may ask questions about the different food groups represented.

In cooperative groups of four, the children in grades 2-3 may rotate to stations/tables designed to help them explore serving sizes with models of selected foods from each food group. Each station should also include a fact card bearing nutrition facts in the form of a riddle or story problem. The fact cards should report the benefits derived from the foods in that food group and simple descriptors of some serving sizes.

Following the exploration of serving sizes, the children may be given three large circles of different colors to represent plates of food for each meal: breakfast (red), lunch (yellow), and dinner (green). Using drawings of food, or pictures taken from magazines or newspaper ads, the children may cut and paste the pictures onto the plates representing breakfast and dinner. The lunch plate, representing the foods from the cafeteria lunch served that day, may be covered with the children's drawings or the written names of the foods rather than pictures from magazine or newspaper ads. Tally marks may be made on a separate sheet to keep track of the number of times each food group is represented in each meal.

Concept Introduction

On the first day of this lesson, only breakfast meals and the cafeteria lunch meal should be investigated by children in kindergarten-grade 1. The following day, the teacher may continue with breakfast or focus on the lunch or dinner meals. The teacher may use a story, poem, or song to introduce the idea of eating foods from each food group in each meal.

Children in grades 2-3 may also benefit from participating in an active role play, song, or rhyme. Afterwards, the teacher may draw the children's attention to The Food Guide Pyramid indicating the number of servings of selected foods. Pictures or plastic models of sample meals (e.g., healthy and not-so-healthy) may be displayed. The children will distinguish between the healthy and not-so-healthy meals and justify their identifications based upon the food groups in each meal. The teacher may ask questions such as the following: How many servings of bread and cereals do you see in this meal? In which meal does this person eat the most from the vegetables food group? What are the names of the foods in these meals? What are the names of the food groups in these meals? Based upon the information on The Food Guide Pyramid, did this person eat all of the servings suggested for each food group in one day? What might happen if this person does not eat enough bread or cereals? What might happen if this person does not eat enough fruit?

Concept Application

Children in kindergarten-grade 1 will select foods from the class floor/table graph (completed earlier in the lesson) to make a healthy breakfast. The results can be drawn on paper plates or paper circles. The children in grades 2-3 may take another look at the class floor/table graph and review the healthy and not-so-healthy foods, the representation of the food groups, and the serving sizes of the foods represented. Afterwards, the children should take a closer look at the foods on the three paper plates they prepared and make any necessary adjustments in food choices and serving sizes (Figure 21.4. The children will write a letter to their parents explaining what they discovered about the three meals regarding food group representation and meeting the number of daily servings recommended.

Closure

The children will help set a table, or several tables, in the classroom or school cafeteria, and eat a model breakfast or lunch. [Note: It may be helpful to let this activity coincide with Grandparents' Day or some other special occasion when guests may be invited and can help with the expenses!]

The children may cut out the foods from the paper plates, leaving a little of the colored paper plate showing around the edges (red for breakfast, yellow for lunch, green for dinner).

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You have been given three circles (plates). Place your small food cards on each of the plates to display what you will eat for each meal. If you can not find a food card you may draw your own.

Place an X in the box when you select a food card for that food group. Write the number of servings in the blank on the right.

Breakfast:

Bread/cereal	servings
Meat/poultry/fish	servings
Vegetables	servings
Fruit	servings
Milk/yogurt/cheese	servings
Meat/poultry/fish	servings

Figure 21.4 *A Possible Tally Sheet for Breakfast. Children Record Data for Breakfast, Lunch, and Dinner and Then Add Tally Marks*

These pictures may then be displayed in any of the following ways: (a) on a large circle/plate showing the foods eaten all day with the pictures of foods from the same food group glued next to each other, (b) on a large triangle cut from construction paper representing The Food Guide Pyramid with the pictures of the foods glued to the appropriate food group sections, or (c) on a pictograph or bar graph showing the same information. Either of these options should be accompanied by at least one sentence describing why the chart shows a healthy meal choice.

Auxiliary Activities

1. Children may explore the number of ways the same food can be prepared differently in the same meal or in the same day. This may be done as a silly exercise to make it a more enjoyable activity for the children. For example, a child may describe a day that he/she had too many potatoes: "I had potato pancakes and hash browns for breakfast, french fries and potato soup for lunch, and potato salad and candied yams for dinner. No bread, fruit, meat, milk, cheese, fats, oils, or sugars? Oh yes, the potato pancakes also counted as a serving of bread, one egg, fat, and sugar." Additional information can include the total number of servings from each food group and what might be changed to make the meals more healthy?
2. Children may justify and identify fractional parts of foods that may be included in a meal as a serving: half a grapefruit, three-fourths of a cup of vegetables, a sixth (grades

2-3) of a cantaloupe. For example, this is about half of a grapefruit because two pieces about this size make the whole grapefruit.

3. Children may identify two-dimensional shapes on three-dimensional objects (e.g., rectangles on cereal boxes, or circles on a box of oatmeal).
4. Children may investigate the concept of area by covering the food group regions on The Food Guide Pyramid (USDA, 1992) using direct comparisons and nonstandard units. The area for each food group is roughly proportional to the number of servings required for that food group in one day [grades 2-3].
5. Children in grade 3 may investigate the possible combinations for getting four servings of milk/yogurt/cheese in a day. For example, using four paper clips, four sugar cubes, four same-colored unifix cubes, or four otherwise identical objects, the children should practice moving the objects around from plate to plate (among the three plates representing breakfast, lunch, and dinner). This activity represents a real-life connection to an often neglected objective found in some third grade curriculums: "Investigate, display, and record all possible arrangements of a given set of objects" (Ohio Department of Education, 1989, p. 128) (Figure 21.5).

Breakfast	Lunch	Dinner
1	1	2
1	2	1
2	1	1
0	4	0
4	0	0
0	0	4
1	3	0
0	1	3
3	0	1
1	0	3
0	3	1
3	1	0

Figure 21.5 *Possible Ways of Getting Four Servings of Milk/Yogurt/Cheese in One Day*

6. Children may investigate serving size information on the Nutrition Facts label found on most packaged foods bought from the grocery store. The children may display and discuss this information according to their interests.

Lesson 3: Food, Calories, and Energy (Grades 2-3)

Objectives

The children will...

1. provide a simple explanation about how food, Calories, and energy are related.
2. consult a Food Calories list to find the number of Calories in a serving of a common food item.

3. sort foods according to high-Calorie and low-Calorie characteristics.
4. combine, order, and compare numbers.
5. collect and analyze data.
6. create a picture graph, bar graph, and/or Venn diagram.

Content

A Calorie (spelled with a capital C) is a measure of the amount of energy a food can provide. Another kind of calorie, a food calorie or kilocalorie, is the amount of heat required to raise the temperature of 1 kilogram of water, 1 degree Celsius. Study of the food calorie is seldom included in the primary school curriculum. The teacher may make the decision, or provide brief information about the two possibilities, then permit the class to vote on whether to spell calorie with or without a capital C.

Our bodies need energy for us to do anything we do: eat, sleep, breathe, run, or play. We eat food to provide fuel for our bodies so we can have energy. Our bodies change the Calories in the food we eat into energy. The greater the number of Calories in a food, the more energy the food provides. Although most high-Calorie foods contain undesirable sugars and fats, a person may choose foods that meet their energy needs in a healthy diet. A good breakfast should supply at least one-fourth of the nutrients and Calories a person needs for one day. A very active person needs to eat foods with a high number of Calories. The number of Calories needed for a child ages 4-8 is approximately 2000. The magnitude of this number is larger than number quantities usually studied by children in grades K-2; however, the teacher may permit the children to gain number sense about these numbers by using base-ten models and/or repeated addition on a calculator. For example, "A cup of whole milk provides 150 Calories. Let's see approximately how many cups of milk it would take to get a whole day's worth of Calories: 150 ...(Each time the equal button is pressed on the calculator, a base-ten flat and 5 longs representing 150 may be stacked together until they form a base-ten block, representing 1000.) Wow, that's more than 10 cups of milk!"

Of course, no one should get all of their Calories for one day from one food like milk. Why? Because we need the nutrients and benefits from the other food groups, too.

Materials

1. Base-10 blocks or other place value manipulatives
2. Examples and nonexamples of serving sizes for various foods (e.g., a 3-oz. hamburger patty made of modeling clay to be compared with a patty of a small hamburger from a favorite fast-food restaurant)
3. Calculators (four-function/arithmetic logic)
4. 18" x 24" strips of construction paper
5. Food picture cards (on halves of 3" x 5" index cards) and pictures of foods from magazines and newspaper ads
6. Data tables providing Calorie information (see Figure 21.6 and cookbooks)

Invoking Prior Knowledge

The teacher may use a KWL exercise to begin this lesson and/or ask questions to highlight the connection between food, Calories, and energy: What have you heard about Calories? What do you think Calories are? Do you think grown-ups prefer foods with a high number of Calories or a low number of Calories? Do you think the same thing should be true for children

Food	Calories
Whole milk, 1 cup	150
Low-fat milk, 1 cup	100
Skim milk, 1 cup	85
Buttermilk, 1 cup	100
American cheese, pasteurized process, 1 oz.	105
Cheddar cheese, 1 oz.	115
Mozzarella cheese, part skim, low moisture, 1 oz.	80
Swiss cheese, 1 oz.	105

Figure 21.6 *Caloric values for some dairy products*

(i.e., low number or high number of Calories)? Think about the different food groups we have been investigating: Which foods do you think are high in Calories? low in Calories? Why?

Exploration

The children should try to identify high-Calorie and low-Calorie foods based upon their guesses. Picture cards should be sorted accordingly, then sorted again based upon food groups. The children may compare their findings in the two sorts and prepare a statement to explain the results. The explanations should include a description of how the picture cards were counted.

The children may also be given empty food containers with the Nutrition Facts label temporarily covered. Working in pairs, the children should sort these foods into high-Calorie and low-Calorie foods, then uncover the Nutrition Fact labels and discuss what they've discovered.

Concept Introduction

The teacher may ask: "Are you surprised by some of the numbers you see? Do you think you see any patterns in the numbers for the various food groups? Which food groups tend to have more foods with high Calories? low Calories? Why do you think this is true?" Following responses to these questions, the teacher may use a list of Food Calories in Common Foods to revisit the classifications made by the children. As foods are confirmed as high-Calorie or low-Calorie, the teacher can help the children articulate the distinguishable characteristics of the foods in each group.

The teacher may also remind children that the reported Calories are based on serving sizes. Additional questions may help children appreciate what happens to the Calorie count when a person eats more or less than a serving.

Concept Application

Given the cafeteria lunch menu, pictures of a model breakfast, and pictures of a model dinner, the children should determine the total number of Calories in each meal and the total for all three meals. Short story problems and/or number sentences may accompany the Calorie counts. The children may use a set of base-ten blocks to compare the number of Calories of foods from the same food group. For example, the number of Calories in a lunchtime cup of frozen vanilla ice milk is greater than the number of Calories in a breakfast time cup of whole milk: 185>150. Estimation, mental mathematics, and calculators may also be used to increase number sense.

Closure

The children should plan a healthy breakfast (approximately 500 Calories) and a healthy dinner (approximately 750 Calories). With some modification, the data organization for breakfast and dinner meals from Lesson 2 may be used. The children may also prepare a collage showing pictures of high-Calorie foods on one side of the paper and low-Calorie foods on the other.

Auxiliary Activities

1. The teacher may invite a nutritionist to demonstrate how the number of Calories in a food item is determined.
2. The children may investigate Calories in various fast foods or cereals and prepare a display to share the results. How many food groups and servings are represented in the fast foods and cereals? A closer look at some of these foods might also reveal a possible reason why the foods provide a high number of Calories (e.g., Is the food fried or does it contain a lot of sugar?)
3. The concept of fourths may be investigated more closely to prepare children to discover that 500 Calories represents one-fourth of the 2,000 Calories recommended in one day for this age group. The children may begin by cutting foods into fourths and verifying why the resulting amounts represent fourths. Eventually, two base-ten blocks may be separated into four equal parts by making the necessary trades: each block traded for 10 flats, the 20 flats then separated into four piles of 5 flats each. Discussion can focus only on the 500 Calories for breakfast, or also include dividing the remaining 1,500 Calories among the two remaining meals and any snacks the child might eat for the day. This activity may also include paper-folding to find fourths.

Lesson 4: Bodies, Food, Cars, and Energy Objectives

Objectives

The children will...

1. relate energy to motion.
2. measure the distance traveled by a car.
3. compare and order different lengths.
4. role play or act out a problem situation.
5. measure lengths using nonstandard units, centimeter, and/or inches.
6. create a table, simple picture graph, or bar graph.

Content

Energy is necessary for doing physical work such as walking, playing, kicking, lifting, or pushing things. Energy even helps us to simply move an arm, leg, finger, or eyelash. The biggest surprise may lie in the fact that energy is necessary for our internal organs to work, too! Without energy, we can not breathe or grow. Although the kindergarten to grade 3 child may have some difficulty accepting the last notion, concrete examples like a heartbeat or swelling of our lungs may be convincing.

Proper diet is necessary for proper functioning of the body because the food we eat supplies the energy for our movement and other bodily functions. Foods that contain protein and starch are our best choices for foods to help us sustain energy throughout the day. These foods mainly come from the bread and cereal group. However, milk and meat also provide protein, and fruits provide sugar that gives us quick energy.

Since energy is necessary for human movement, the concept of energy may be extended to the movement of cars. Gasoline supplies the energy needed for the running of a car. (The different kinds of gasoline—regular and supreme—might even be loosely compared to low-energy and high-energy foods.) The less gasoline a car has, the shorter distance it will travel. In the case of toy cars with wind-up springs, the energy comes from the winding of the spring. The distance traveled by a wound-up car depends (within certain limits) on the number of windings given to the spring.

Materials

1. Pictures of the three main food groups: bread/cereals, vegetables/fruits, and meat/fish/milk.
2. Small pictures of the food groups for children.
3. A paper circle cut-out, for each child, divided into three equal parts representing breakfast, lunch, and dinner, or three wide strips of paper (to facilitate a picture graph or floor graph) each marked to represent breakfast, lunch, and dinner.
4. Battery-operated cassette tape player and a cassette tape with soft, fun music.
5. Small toy cars with winding springs (the distance traveled by these cars depends on the number of windings of the spring).
6. Children can use 2.5 cm X 30 cm long pieces of cardboard, rope, rulers, or linkable manipulatives, depending on their ability to read.
7. Straightedge.

Invoking Prior Knowledge

In the early morning, the teacher may turn on a cassette player with soft, fun music. At times the sound may be turned down very low, but the cassette player should be left on. Periodically the teacher may increase the volume. The children should notice that the rhythm of the song begins to drag as the battery gets weaker. As the children begin to comment about the strange sounds, the teacher may ask the children to conjecture about the results. Then the teacher should ask the children if they have ever felt like the cassette player seems to be *feeling*. If so, when and why?

The teacher may also show pictures of children doing daily activities with some children more active than others. The teacher may ask questions such as: Which children in the pictures seem to have lots of energy like the cassette player did at the beginning of the day? Which children in the pictures seem to have energy like the cassette player did later? Which children do you think ate breakfast? Why? How do you feel when you have not eaten for a long time? Do you feel like playing when you are hungry?

The teacher may ask other questions to draw attention to the connection between food and energy, and connections between this lesson and the previous lessons.

Exploration

Given toys that are powered by hand-cranking, winding up, or pumping, the children will explore how the toys perform when they have various amounts of energy. To share the results, the children should draw two pictures of their favorite toy on a sheet of paper. One picture will show how the toy performed when it had little or no energy; the other will show how the toy performed when it had much energy.

Concept Introduction

With a story, rhyme, or play the teacher may introduce the concept of energy from food, or food as fuel for our bodies. The children may role-play as they depict children with lots of energy, compared to children with little energy; and children who ate good energy-providing foods, compared to children who did not.

Children in grades 2-3 should take another look at the paper plates showing what foods were eaten for meals (in previous lessons). Reviewing previously used charts, graphs, and/or The Food Guide Pyramid, the children should discuss some of the benefits provided by the foods in the food groups. For example, breads and cereals provide energy; vegetables and fruits provide vitamins and minerals; sugars in fruits also provide energy; and meat, poultry and fish provide stronger muscles.

The teacher may ask the children such questions as the following: Which foods do you think help our bodies like gasoline does in a real car, or winding a toy car? What might happen if we do not eat enough bread or cereals? What might happen if we do not eat meat, poultry, or fish? How many people in class today feel like they have lots of energy? What did those people eat for breakfast this morning?

The teacher may wind a car a number of times and have the children count along for each wind. The class should note the distance traveled by the car. The teacher may pose the following problem: "My car didn't have enough energy. I want it to go farther next time. Should I wind the car more or less times than before? Why?" The teacher should demonstrate according to the children's responses, then discuss the idea that increased energy permits increased motion, and increased energy comes from more winds for a toy car, better gas for a real car, and eating foods that provide more energy for the human body.

Concept Application

The children in kindergarten-grade 3 may work in cooperative groups to discover a relationship between the number of windings of a car and the distance the car will travel. Results may be recorded on a sheet similar to Figure 21.7. The children should wind the cars and let the cars go. Before measuring the distance, the children should estimate the distance in non-standard units (e.g., rope-lengths, straw-lengths, unifix-cube-lengths) and/or standard units (i.e., centimeters or inches). After measuring, the groups should discuss how they might change the way they are estimating to get estimates that are closer to the actual measurement. The children should also focus on making a statement about how the number of windings compare with the distance traveled by the car. The experiment should be repeated a number of times before the children provide a summary of findings.

Children in grades 2-3 may do the above activity in conjunction with two or three more activities and rotate to learning stations. In another learning station, the children may investigate a problem printed on a large card that relates to gasoline in a real car: What difference will it make if your car has a little amount of gas or a large amount? Two cars were almost empty. One car got two gallons of gas at the pump. Use two 1-gallon containers of rice, sand, or water colored with food-coloring to represent the amount. The other car got four gallons of gas at the pump. Use four 1-gallon containers. Which car do you think will be able to travel farther before stopping? Design an experiment to help convince the class of your answer. Be prepared to share your opinions and your findings.

How many winds?	How far? (estimate)	How far? (actual measurement)	Comparison (estimate vs. actual)
Sample	6 straws long	7 straws long	6 < 7
Trial 1			
Trial 2			
Trial 3			

Figure 21.7 *Estimation and Measurement Table for Distance Traveled*

A third learning station could involve the children in selecting foods from magazine or newspaper pictures to prepare high-energy meals that represent the recommended daily servings from the food groups.

A fourth learning station could involve children doing a high-energy activity like jumping up and down, or repeatedly picking up and putting down a book. The children may do the activity until they are tired, stop to drink a tiny cup of water, and return to the activity. Did they gain more energy? Stop to taste a portion of a fruit or a piece of bread, and return to the activity. Did they gain more energy?

Closure

The children may divide a large sheet of paper into two nearly equal parts. On one side, the children should draw pictures of foods that should be eaten to gain lots of energy. The other side may show children doing activities that require lots of energy. These drawings may be shared with the class as the children take turns describing their pictures and explaining what they understand about food and energy.

Children in grades 2-3 may work in cooperative groups of 4-6 to create a role-play that shows the importance of energy and the role of certain foods in providing energy. The children may try to write the play, but may also use audio tape or videotape with limited details written on paper. Children who prefer to do so may choose to prepare a story book or comic book instead. Picture graphs, bar graphs, and drawings may be included to represent the data in the story. The stories and plays may be assessed based upon their alignment with the mathematics and science objectives cited for the lesson.

Auxiliary Activities

1. Children may read stories about marathon runners and the phenomenon known as carbo-loading: increasing carbohydrate intake before a run to get an energy boost. Charts and graphs may be used to describe the quantities of pasta and carbohydrates. The teacher should present both advantages and disadvantages for this practice.

2. Children may make a picture book entitled "Things I'll do differently now that I know more about foods," or "There's more to food than just eating it!" The book may be compiled as an open-ended exercise with limited guidelines, or it may be compiled to address specific Performance Indicators found in *The National Health Education Standards* (Joint Committee on Health Education Standards, 1995).

Summary

Integrating science and mathematics lessons is a commendable activity because the two subjects are integrally related by many common skills and processes. However, sound educational goals must drive both the early childhood curriculum and the subsequent efforts in subject integration. The greatest benefits of curriculum integration may be obtained when topics are taught in a meaningful context, with active child participation in the formation of concepts and ideas.

The authors of this chapter have shared examples of integration with hopes that the specific context of food and energy does not overpower the general messages regarding procedures for efficient subject integration. It is commendable that most early childhood teachers teach concepts within thematic units; yet it is critical that the activities within those units retain integrity for each subject being integrated. Integrity can be maintained when the graded course of study is consulted as activities are selected. Furthermore, the activities within those thematic units must be developmentally appropriate; and permit the children to continually discover, reflect, and synthesize information which helps them to better understand the world around them.

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Appendix A

Some Children's Books to Read

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Veitch, B., & Harms, T. (1981). *Cook and learn: Pictorial single portion recipes—A child's cook book.* Menlo Park, CA: Addison & Wesley Publications.
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Appendix B

Recommended Daily Servings and Sizes for School Age (primary grades) Children

Bread & Cereal	7-8 servings
Vegetable & fruit	5-6 servings
Meat, fish, & poultry	2-2.5 (2-3 oz.) servings
Milk, yogurt, & cheese	3-4 cups

Serving Sizes

Breads, cereals, rice, and pasta:

One slice of bread; one half bagel; 1 ounce of ready-to-eat cereal; 1/2 cup cooked cereal, rice, or pasta; 5-6 small crackers

Vegetables:

1 cup raw, leafy vegetables; 1/2 cup cooked or chopped raw vegetables; 3/4 cup vegetable juice

Fruit:

1 medium apple, banana or orange; 1/2 cup chopped, cooked, or canned fruit; 3/4 cup fruit juice

Meat, poultry, fish, beans, and nuts:

2-3 ounces cooked lean meat, poultry, or fish; one egg; 1/2 cup of cooked beans; 2 tablespoons peanut butter; 1/3 cup of nuts

Milk, yogurt, and cheese:

1 cup milk or yogurt; 1 1/2 ounces natural cheese, 2 ounces processed cheese

Chapter 22

Literature: Keys to Learning Mathematics and Science

Jan E. Downing & Tammy Benson

Educators tend to agree that a constructivist view of learning–supported by theories that reflect philosophies of Piaget, Bruner, and Dewey—is the basis for appropriate methods to teach young children mathematics and science. The mystery today lies in determining appropriate strategies to implement these theories. The purpose of this chapter is to discuss and provide examples of teaching strategies that effectively integrate literature with mathematics and science. Included in this chapter is a close examination of some of the most commonly used children's books with some innovative ideas for activities and lesson plans that are designed to provide the keys to unlocking this mystery. These keys can open doors to meeting American Association for the Advancement of Science (AAAS), National Academy of Science (NAS), and National Council of Teachers of Mathematics (NCTM) standards by utilizing creative choices in literature as a backdrop to a learning environment that becomes motivating, interesting, and relative to the young learner.

Integration—the Key to Meaning

An integrated curriculum encourages children to learn in a way that is most natural to them rather than a segmented approach of learning mathematics, science, literature, and other subject areas. When young children are hard at play constructing club houses from cardboard boxes, building castles with Legos, discovering new ways to reach the cookie jar mom has strategically put away, acting out *The Three Little Pigs*, or even having a book read to them about Native Americans, they are learning in a natural integrated fashion. Some advantages of teaching children through an integrated curriculum include (a) increasing and holding children's interest; (b) opportunities to practice and develop concepts and skills; and (c) flexibility in presenting various themes left to the discretion of the teacher.

Literature—the Key Connecting Theory and Practice

A constant challenge in early childhood education continues to be the ability to bridge the gap between a constructivist theory and its practical application in daily classroom activities. Literature has been utilized successfully for teaching skills and concepts in a meaningful and relevant way which is more motivating to children. As children have been immersed in quality literature, great strides have been accomplished in motivation and learning. A literature-based approach is being utilized as a springboard for teaching various content areas, including mathematics and science.

As educators realize the impact literature has on emergent literacy, the focus of early childhood programs will continue to be on the use of quality children's books. Cullinan (1987) has described literature as the natural way to learn to read. Literature has also been successful as a mechanism to integrate the curriculum. An integrated approach makes sense because learning is not segmented into meaningless fragments of information.

Utilizing books in early childhood programs offers many benefits to young children. Research supports the use of literature to provide a structure of story, increase listening and oral language skills, motivate children to read, provide a means for introducing and reinforcing new ideas and skills, and encourage positive attitudes about learning. Sawyer & Comer (1996) also emphasize the value of literature to inform and excite children, contribute to the development of a positive self-esteem and acceptance of others, and to help children connect with people sharing stories and people within the stories. Books that deal with a specific focus on mathematics or science allow children to actively construct knowledge about new and interesting ideas. Concepts that may have seemed complicated and uninteresting when introduced alone can come alive for young children through the use of quality literature.

Finding Quality Literature

As educators begin their search for quality literature, many treasuries of books can be found which provide guidance. Jim Trelease's (1989) *New Read-Aloud Handbook* offers excellent references for quality children's books, including appropriate grade levels, summaries, and lists of related books. Regie Routman (1988) provides an excellent resource guide in her book *Transitions*. This book includes a specific reference section for books that relate to mathematics and science, as well as other quality literature selections. Routman (1994) has expanded her resource guide to include recommended literature for children K - 12 in her new book, *Invitations*. Other resources for finding quality books include Sawyer & Comer's *Growing Up with Literature*, Cullinan's *Children's Literature in the Reading Program*, Morrow's *Literacy Development in the Early Years*, and Lynch-Brown & Tomlinson's *Essentials of Children's Literature*.

Other ideas for gathering quality books include browsing the local library, visiting the media specialist and other classroom teachers, and attending professional conferences regularly. When looking for specific resources for mathematics and science integration through literature, Marilyn Burns (1992) has created in-service courses and resource guides on connecting mathematics with creative ideas in children's books. Brandon, Hall, & Taylor (1993) provide examples of literature which focus on teaching mathematical concepts such as number sense and numeration, whole-number operations and computations, geometry and space, measurement, statistics and probability, fractions and decimals, and patterns and relationships. Butzow and Butzow (1989) describe ways to use literature as a springboard to science by providing the connections between science topics, literature titles, and relevant activities.

Evaluating Quality Literature

When evaluating children's literature, attention should be directed to the characters, plot, style, and illustrations (Butzow & Butzow, 1989). Children prefer stories with characters that they can identify with and that remind them of real life experiences. Animal characters are great favorites of young children. Stories such as *The Tortoise and the Hare* teach lessons that children can relate to through interesting animal characters. The plot should involve a logical sequence of events, be motivating to children and provide a successful resolution to problems identified. Style and illustrations help add to a book's appeal to young children. Illustrations can help children to understand the story.

As teachers choose quality literature to teach mathematics and science, they need to ask themselves four major questions about the books:

1. Can I read the book with enthusiasm and motivation?
2. Is the story content appropriate for young children?
3. Will the book encourage positive feelings about reading?
4. Does the book promote the development of mathematical and science concepts and skills?

When teachers consider the kinds of appropriate books and the purpose of sharing them, they can make wiser judgments about which books should be selected.

Activities and Projects Utilizing Literature: Unlocking the Mystery

Once quality children's books are identified, strategies and methods are needed which incorporate them in a developmentally appropriate way. Mathematics and science skills and concepts can be matched with children's books to provide an exciting avenue for children's holistic development. Once educators are convinced of the motivating power of literature, practical ways to utilize this literature can be implemented.

Teaching Mathematics and Science Through Literature

Language arts lessons (which include the use of literature) monopolize the majority of instructional time in the day of an early childhood curriculum. The emphasis on reading and writing makes learning in other subject areas possible. Creating opportunities to integrate other subject areas with literature can make lessons more interesting, relevant, and motivating. Children's literature can spark the imagination of a young child in a way in which worksheets and textbooks can not. Although the acquisition of factual knowledge remains important, even more important is the idea that children understand the relationships of these facts to the world in which they live. Literature can provide a rich and motivating environment filled with intriguing scenarios and the potential for great mathematics and science lessons waiting to be discovered and explored. Connecting literature to some of the familiar daily events that occur naturally in children's lives is a powerful strategy to extend mathematical and scientific thinking in the classroom.

Using literature can also help children realize the variety of situations which can use mathematics and science for real purposes. For example, children can be motivated to learn more mathematics to help solve a character's problem and in doing so feel that they have made a significant contribution to the character's success.

A major purpose of studying mathematics and science is allowing children opportunities to use basic process skills to understand and explain their world. Children can learn these problem solving skills through relevant literature activities. Ways to connect literature with skill development include activities which motivate children while giving them practice implementing those problem solving skills. Teaching mathematics and science in a holistic way involves objectives and activities that integrate the curriculum while giving specific practice in skill development.

Examples of literature to teach mathematics and science can be categorized into thematic unit topics. Science units can be implemented to teach science process skills, reinforce vocabulary and concepts, enhance reading and writing development, and integrate other curricular areas. A bibliography at the end of the chapter includes a list of science topics and quality literature that reinforces these themes.

Since the use of literature is beneficial to children, especially in helping them make sense of mathematical and scientific concepts, it should be used often in the classroom as a tool for integrating. However, this doesn't mean that every piece of children's literature must be turned into a mathematics or science lesson. The enjoyment of reading should continue to be promoted as children realize that a good story or book can be an enjoyable, relaxing experience.

Matching Books with Concepts and Skills

There is no shortage in the market for good children's books from which fun and interesting mathematics and science lessons could be taught. This section is devoted to providing a guide when selecting children's literature to match appropriate mathematical and scientific concepts and skills. At the end of this chapter is a lengthy list of selected children's literature which represents a small portion of the enormous selection of books waiting to be discovered by the creative teacher.

Once a theme or book is chosen, the teacher must decide how to connect the literature with specific concepts or skills to serve as the vehicle for a lesson. One effective way to achieve this goal is to make a curriculum web for each book or topic idea. As the teacher brainstorms ways to integrate the curriculum based on a particular book, it is easier to apply specific skills to these books. In *Cloudy with a Chance of Meatballs*, many activities can be implemented which emphasize mathematical and scientific process skills.

1. Children can *predict* which food they believe will fall next. Ideas can be charted and predictions can be checked as the story is read.
2. Children can *observe and record* cloud formations in the sky. These formations can be compared with clouds from the book.
3. Children can *measure* rainfall using a glass as well as utilize other weather instruments.
4. Children can *categorize* various foods into breakfast, lunch, and dinner foods. By using paper plates, children can plan their next meal from the "clouds."
5. The children can *describe and compare* life in "Chewandswallow" with life in their town.
6. The children can *graph* their favorite food that falls in the story. Children can then write about the reality of eating the same food all the time.

Matching the literature with concepts and skills may be the most difficult step to achieving lesson harmony. Following is a list of developmentally appropriate activities utilizing children's literature to focus on particular skills and concepts.

Activity 1. ***M & M Counting Book* (McGrath, 1994)**

Concept Emphasized: Classification
Skills Emphasized: Adding and subtracting
Additional Materials: Cup of M & M's for each child, blank book for story, crayons
Description of Activity:

As this book is read, children will listen carefully and follow directions such as add one orange M & M, eat three green M & M's, etc. The children will be guided through practice counting, classifying, adding and subtracting as this book is read. After reading the story, the children will make a book showing different things that can be done with M & M's. The children will use left-over M & M's for trying activities before writing and illustrating their book. In pairs, children can share books and continue counting, adding, and subtracting with the illustrated M & M pictures.

Activity 2. ***The Day That Monday Ran Away* (Heit, 1969)**

Concept Emphasized: Calendar
Skill Emphasized: Graphing
Additional Materials: Poster paper and markers
Description of Activity:

Have children conduct a survey to determine their favorite day of the week and graph the results. Ask children to explain their choices.

Activity 3. ***How Many Snails?* (Giganti, 1988)**

Concept Emphasized: Classification
Skill Emphasized: Counting
Additional Materials: None
Description of Activity:

Play a game where children look around the room noticing the number of various objects in the classroom. Taking turns, let each child in the class ask, "I wonder how many _____ (child names object of choice) are in the room?" Encourage the others to count and classify objects aloud. Children may ask "how many clocks are in the room?", "how many teachers?", etc.

Activity 4. ***The Half-Birthday Party* (Pomerantz, 1984)**

Concept Emphasized: Half and whole (Fractions)
Additional Materials: Chart paper, markers
Description of Activity:

After reading *The Half-Birthday Party*, the teacher will guide the children through the creation of a chart with two columns. Children will fill one column with items from the story which can be successfully divided in half. The other column will consist of items from the story which could not be divided into halves. Children will then be asked to name other items not discussed in the story that can be divided into equal halves and add to their chart.

Activity 5. ***Grandfather Tang's Story* (Thompert, 1990)**

Concept Emphasized: Spatial visualization
Skill Emphasized: Identifying geometric shapes
Additional Materials: Tangrams
Description of Activity:

Have children make the shapes of the characters in the story. These include a rabbit, dog, squirrel, hawk, turtle, crocodile, goldfish, goose, and lion. The patterns can be found in the book. You can also encourage children to invent their own shapes.

Activity 6. ***How Big Is a Foot?*(Myller, 1962)**

Skill Emphasized: Measuring
Additional Materials: Cutouts of feet (2 sizes - large and small).
Description of Activity:

Divide the class into 4 groups. Give two groups several large "foot" cutouts and give the other two groups many small "foot" cutouts. Give class a list of items to measure using the foot cutouts. Ask children why there is a difference in the number of feet used to measure these items. For example, one group may determine that a table has a measurement equal to 7 large foot cutouts while the same table measured by a different group is equivalent to 12 small foot cutouts. Ask children to explain some problems with using these types of measurements.

Activity 7. ***The Doorbell Rang* (Hutchins, 1986).**

Skills Emphasized: Cooking, multiplying and dividing
Additional Materials: Paper, pencils, and chocolate chip cookies
Description of Activity: Have children use simple equations to tell the story in numbers. Next, have children plan to make chocolate chip cookies. The recipe says it will make

five dozen cookies. Have children determine how many cookies each will get to eat if the recipe is followed correctly. Make the cookies and see.

Activity 8. *Fast and Funny Paper Toys You Can Make* (Churchill, 1989)

Skills Emphasized: Visual discrimination, writing, problem solving
Concepts Emphasized: Spatial visualization, shapes
Additional Materials: Origami paper or colored typing paper
Description of Activity:

Assist children in making the different items described in the book. Provide additional patterns for children who finish quickly. See how many different shapes children can recognize in the objects they make. Have children write their own stories about the origami toys and animals they have created.

Activity 9. *Sam Johnson and the Blue Ribbon Quilt* (Ernst, 1983)

Skill Emphasized: Patterning
Additional Materials: Geoboards, pattern blocks (other items can be used in place of pattern blocks - buttons, color tiles, etc.).
Description of Activity:

Divide children into groups of twos. Instruct children to take turns creating patterns on the geoboard and having the other copy it. Do the same with pattern blocks. Encourage children to invent their own patterns, designs, and murals using pattern blocks.

Activity 10. *Around the Clock With Harriet* (Maestro, 1984)

Concept Emphasized: Time
Skill Emphasized: Sequencing
Additional Materials: Poster paper, markers, clock
Description of Activity:

Have children create a simple time line illustrating the sequence of events that take place during a normal school day. Display approximate times of each event. The children can then draw pictures of three important parts of their day and a corresponding clock with the approximate time of these activities.

Activity 11. *The Button Box* (Reid, 1990)

Skills Emphasized: Classifying, counting
Additional Materials: Various kinds of buttons
Description of Activity:

The children will discuss similarities and differences of buttons in the story *The Button Box*. The children will then work in groups to categorize buttons into groups by color, size, number of holes, texture, and other attributes. The children will then label their groups and share with the class.

Activity 12. *The Enormous Watermelon* (Parkes, & Smith, 1986)

Concept Emphasized: Plant growth
Skills Emphasized: Comparing, estimating, measuring
Additional Materials: Watermelons, cantaloupes, grapes, oranges, apples, tape measure, markers, chart paper, paper
Description of Activity:

After reading *The Enormous Watermelon*, the children will estimate sizes of various fruit. The children will then measure the fruit and compare the different sizes. A chart will be made which shows the estimated guess, and the actual size of the fruit. The children will then brainstorm different descriptive words which could adequately describe the various fruit. The children will then draw their two favorite fruits and tell about their similarities and differences.

Activity 13. *Make Way for Ducklings* (McCloskey, 1969)

Concept Emphasized: Animal habitats
Skill Emphasized: Comparing, Venn diagramming
Additional Materials: Chart Paper, marker, pictures of farm/country life and postcards of big cities

Description of Activity:
The teacher will reread *Make Way for Ducklings*, asking the children to notice the different lifestyles of the ducks from a farm existence to city life. After reading the story, the children will compare pictures of farms with postcards of cities. The children will help the teacher create a Venn diagram which details differences between farm and city life. The children will then complete their own Venn diagram contrasting differences of their choice.

Activity 14. *Strega Nona* (dePaola, 1975)

Concept Emphasized: Sense of taste
Skills Emphasized: Demonstrating, measuring, comparing
Additional Materials: Chart recipe for spaghetti, cookbooks, ingredients for spaghetti, cooking utensils, measuring cups

Description of Activity:
After hearing *Strega Nona*, the children will demonstrate how to make the very best spaghetti, using various kinds of pasta. Four different groups will make spaghetti for a taste party. Children will then compare spaghetti and share in a class made spaghetti cookbook.

Activity 15. *Simon Underground* (Ryder, 1976)

Concept Emphasized: Soil characteristics
Skills Emphasized: Describing, observing
Additional Materials: Soil samples, word bank of describing words, paper for class mural, paints

Description of Activity:
After reading the book, children will describe soil samples brought to class. From a bank of words, children will write about the different textures, colors, etc. of the soil. Children will then create a class mural illustrating and describing various soil samples.

Activity 16. *The Big Balloon Race* (Coerr, 1981)

Concept Emphasized: Density of gases
Skills Emphasized: Estimating, experimenting
Additional Materials: Balloons, paints, milk cartons to decorate for the bottom of balloon, helium

Description of Activity:
After reading this book, children will create their own balloons for a race. They will estimate how high balloons will go with air or helium. After balloons are filled and released, children will observe and discuss results.

Activity 17. ***Stone Soup*** **(McGovern, 1986)**

Concept Emphasized: Greater than/less than
Skills Emphasized: Graphing, cooking
Additional Materials: Floor graph, various vegetables brought by children, pot, ingredients for soup, stone, recipe chart
Description of Activity:

After reading *Stone Soup*, children will bring a vegetable to the floor graph. After the concrete graph is completed, children will count, add, subtract, and identify greater than/less than. The children will then help measure and add ingredients for making their own Stone Soup. The teacher will record the concrete graph on a wall chart for future reinforcement of graphing skills.

Activity 18. ***Follow your Nose*** **(Showers, 1963)**

Concept Emphasized: **Sense of smell**
Skills Emphasized: Predicting, interpreting, recording data
Additional Materials: Variety of objects to smell in plastic film containers
Description of Activity:

After reading the story, the teacher will pass around numbered film containers with various smells. The children will predict the source of the smell and record their predictions on paper. The children will continue their practice in interpreting various smells in a learning center "Smelly Box."

Activity 19: ***A Cane in Her Hand*** **(Litchfield, 1976)**

Concept Emphasized: Sense of sight
Skill Emphasized: Observing
Additional Materials: Blindfolds for children
Description of Activity:

After reading the book *A Cane in Her Hand*, the children will discuss the importance of our eyes. The children will then go on a nature walk around the school. During the last part of this walk, the children will be blindfolded. After the blindfolded part of the walk, children will be more aware of the value of observing. Have children illustrate items from the walk to see how many observances can be recalled.

Activity 20: ***The Carrot Seed*** **(Krauss, 1945)**

Concept Emphasized: Plant growth
Skills Emphasized: Predicting, observing, recording data
Additional Materials: Carrot seeds, cups, soil, chart paper
Description of Activity:

After hearing the story, the children will each plant their own carrot seed. They will keep observing journals to record the activity of their plants.

These activities reflect the creativity that can become an integral part of everyday mathematics and science lessons. Many of the activities can be adjusted and applied to other motivating pieces of literature. These activities should be viewed as a stimulus and guide for originating other activities which further advance the connection of literature with mathematics and science.

Bringing it all Together!

When mathematics and science are integrated with the language arts curriculum through creative, problem-solving activities, higher levels of learning are achieved. Mathematics and science experiences can become a natural part of book-sharing in daily classroom activities.

As teachers begin to bring it all together, sample lesson plans may be beneficial. Included are several examples of how one piece of literature can be effectively used to teach and reinforce mathematical and scientific concepts and skills through developmentally appropriate activities. These ideas can be used as springboards for additional creative thoughts and actions.

The Grouchy Ladybug

Background: From sunrise to sunset a very unpleasant "grouchy" ladybug looks for someone to fight. By the end of her weary day, the tired and sad ladybug learns that it pays to be polite.

Related Concepts:

Mathematics—time, sequencing

Science—food chain, defense mechanisms of animals, mutual cooperation, classification of animals, rising and setting of the sun.

Activities:

Lesson Plan #1. A Day is a Day

Skills:	time and comparing
Materials:	Poster paper, crayons
Objective:	Children will create their own personal timeline using the times illustrated on the clocks in the story.
Set:	Show a clock to the class. Discuss time and how we use time in our daily lives. Ask children about significant "times" of the day. Show book *The Grouchy Ladybug* and discuss what time meant to her.
Body:	The teacher will demonstrate the concept of a time line on the board as the story about the ladybug is reviewed. A model timeline of the story events will be created. Children will work in groups to create their own timeline which should include a list of activities describing where the children are and what they are doing at each time. Create a timeline for a school day and another for a weekend day. Encourage children to compare and discuss differences. Refer to the pictures in the book noticing the position of the sun on each page (through out the day). This detail could be added to the timeline. Make an effort to display a large portion of children's work. Timelines make interesting wall covers!
Conclusions:	Review the significance of a timeline with children. Allow children time to share their time lines.

Lesson Plan #2. Counting Ladybugs

Skills:	counting, adding
Materials:	Dried lima beans (one side painted red, the other side painted black) Black spots can easily be added using black marker which become manipulatives (ladybugs) for children to count and add. Leaves—can be made from green construction paper, fun foam, or green felt.
Objective:	Children will practice counting and adding ladybugs.
Set:	how a picture of the grouchy ladybug. Discuss characteristics of the insect. Pass out manipulatives (ladybugs) and discuss similarities and differences between manipulatives and real ladybugs.
Body:	Give each child (or group of children) a leaf for their ladybugs. Instruct children to cup the ladybugs in both hands, shake and gently drop onto leaf. Count the number of ladybugs that fall upright (red side showing)

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and the number of ladybugs that fall upside down (black side showing). Encourage children to write the problems on paper. Children may want to write word problems using their numbers and ladybugs.

Any type of two colored counters will work nicely for this activity if time does not allow for the making of the ladybugs. You could even let the children make the ladybugs themselves with non-toxic paints.

Conclusions: Review concepts of counting and adding with children. Let them share their created problems.

Lesson Plan #3. Classy Animals

Skills: observation, classification

Materials: *The Grouchy Ladybug*, poster paper, clippings of pictures and photographs of animals in each class.

Set: Begin the activity by sharing many pictures and photographs of animals in different classes noting the different characteristics of the animals.

Body: Children will share characteristics of different classes of animals. Pictures shown in introduction will be placed on a chart designating different classes of animals. Children will help the teacher create this chart. Then, children will work in groups to make a class collage classifying animals such s mammals, birds, reptiles, crustaceans, or insects. After children have identified the correct class, they will place the animal on their group collage. Display children's work so that they can view the collages for future reference. Then go to the book, take each character and decide which class it belongs. Children can draw pictures of each animal and these can be added to the collages.

Conclusions: Share collages with class. Review characteristics of different classes.

Lesson Plan #4. Ladybugs are Insects !

Skills: observing, comparing

Materials: *The Grouchy Ladybug*, picture of a variety of insects, poster paper, markers

Set: Bring a real ladybug to class for children to observe. Discuss and chart descriptions of the ladybug.

Body: Observe pictures of the ladybug from the book. Show children pictures of other insects asking them to find similarities. List or have children draw these on poster paper. Of course answers will vary, but here are some observations they should and probably will notice. For example, both ladybugs and other insects have a head, six legs, wings, two eyes, and two antennae. Guide students through the creation of word problems about the insects. For example, if three ladybugs land on a leaf, how many antennae will you see? Use this information as an opportunity for problem solving practice.

Conclusions: Children will share their observations and review descriptions of insects.

From these four lesson plans, teachers can see the benefits of reviewing how we use quality literature and the need to search for various ways to extend knowledge through the avenue of great children's books. Other books previously mentioned in the chapter can certainly be utilized in much the same way. As educators' awareness of the motivational power of literature increases, great strides can be made in instruction and learning.

Suggestions for Holistic Learning

As teachers find themselves looking to literature as a way to introduce, teach, and reinforce skills and concepts, helpful hints for classroom implementation are needed. The following is a list of classroom-proven strategies to aid teachers in their creative use of literature as an instructional tool.

1. Become familiar with a variety of literature (wide selection, writing styles, and topics) that will make matching children's interests easier.
2. Regularly browse the library for new additions to your literature collection.
3. Attend professional conferences and other educationally related seminars where you can exchange ideas with other teachers.
4. Set up a cooking center with recipe books and books about cooking displayed to encourage the integration of mathematics and science with literacy.
5. Encourage children to notice and repeat patterns found in selected literature. Children can illustrate patterns if applicable.
6. In some cases, before problem solving can effectively occur, it may be necessary to read all or parts of the story 2-3 times.
7. Solve word problems presented in the literature.
8. Encourage discussion about stories. Have children draw and discuss (share) the strategy they used to solve problems presented in literature.
9. After giving instructions for activities, ask one or two children to explain the directions to their classmates.
10. Create a risk-free environment in class which encourages open communication.
11. Condition yourself to be accepting, supportive, and open to the variety of responses and solutions children might offer.
12. When solving mathematics or science problems, permit children to use concrete objects to represent items or characters in the story.
13. Encourage children to act out scenarios.
14. Have children create their own stories.

Discoveries: Assessing Mathematics and Science

As innovative and creative teaching strategies are implemented, alternative assessment techniques must also be developed. However, one of the most effective assessment strategies is "old fashioned" teacher observation. Teachers develop and fine tune their own skills of observing children learning with increased familiarity with their children and experience. Semantic mapping before and after instruction is an excellent technique in determining how much learning has occurred. A couple of advantages to using this strategy include (a) being very easy to interpret and (b) providing a clear visual model that even children can use to assess their own learning. The children's ability to communicate knowledge can be assessed with the use of creating graphs, lab reports, journal writings (or drawings-depending on the age of the children).

Journal writing in mathematics has recently been used as a way of discovering how a child thinks mathematically. With careful examination, a teacher can determine the level of mathematical reasoning ability of each child and a journal can provide an open window to the mind of the child. These entries can provide a means of detecting certain problem areas for children and providing necessary clues to the concerned teacher as to what strategy(ies) would best benefit the child. It is safe to say that journals are no longer restricted to language arts but have been found to be an effective assessment strategy for mathematics and science. Journal entries following a science activity allows children to interpret findings in discovery learning activities. Sometimes children's misconceptions can be easily detected and addressed as a result of utilizing journals as a form of assessment in science. Venn diagrams can provide insight to children's ability to recognize differences and relationships between concepts and ideas. These are just a few methods for assessing children in a more developmentally appropriate way.

As children add pieces of work to their portfolio, mathematics and science selections should not be overlooked. When mathematics and science are integrated through literature, various products of this work result. These products are excellent additions to a child's own portfolio. Examples of these products include:

Journal/learning log entries about mathematics and science lessons.

Charts and graphs.

Responses to literature (audio-taped and videotaped).

Entries from observation notebooks.

Photographs of child creations/group work.

Examples of child recordings of mathematics problems.

Anecdotal records from teachers based on observation.

Checklists of relevant science and mathematical process skills.

Any other data reflecting a child's cognitive and social growth.

These are just a few of the examples of portfolio contents. As teachers work with these activities, they can look to new ways to verify a child's growth and development. A personal portfolio is one of the best ways to document the complexity of children's growth in early childhood education.

Summary

Literature has shown itself to be an effective key to reaching children and motivating them to learn all content areas. Considering the great need for children today to become proficient in areas of mathematics and science, literature cannot be overlooked as a method for enhancing child growth in these areas. As teachers confront the mystery of how to teach mathematics and science process skills, literature is revealed as a promising solution. This chapter briefly reviewed the appropriate keys for teaching mathematics and science through the use of quality literature in early childhood programs. A thorough list of quality children's books for teaching mathematics and science was included to serve as a guide for teachers interested in motivating children to learn through great books!

The activities and lesson plans presented are designed to offer guidance and support for teachers who are struggling to find answers in mathematics and science education. These activities have been field-tested successfully and are in congruence with standards set by NCTM, NAS, and AAAS.

Using literature to teach mathematics and science is effective for instilling a love for reading and making mathematics and science relevant to the young learner. These ideas can serve as a stimulus for additional methods and strategies promoting lifelong learning for young children. Utilizing literature to bridge the gap between educational theory and practice is certainly a step in the right direction. Continue the search for opportunities to integrate quality children's books with other subject areas, and remember; you are limited only by your imagination!

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Routman, R. (1988). *Transitions: From literature to literacy.* Portsmouth, NH: Heinemann.

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Sheffield, S. (1995). *Mathematics and literature (K - 3) book two.* White Plains, NY: Mathematics Solutions Publications.

Sovchik, R. (1996). *Teaching mathematics for children.* New York: Harper Collins College Publishers.

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Trelease, J. (1989). *The new read aloud handbook.* New York: Penguin Books.

Whitin, D. J., & Wilde, S. (1992). *Read any good math lately?: Children's books for mathematical learning.* Portsmouth, NH: Heinemann Educational Books.

Quality Literature to Teach Mathematics

Addition and Subtraction

Brenner, B. (1989). *Annie's pet.* New York: Bryon Preiss Visual Publications.

Christelow, E. (1989). *Five little monkeys jumping on the bed.* New York: Clarion Books.

De Paola, T. (1989). *Too many hopkins.* New York: G.P. Putnam's Sons.

Dunbar, J. (1989). *A cake for Barney.* New York: Orchard Books.

Gisler, D. (1991). *Addition Annie.* Chicago: Children's Press.

Walsh, E. S. (1991). *Mouse count.* New York: Harcourt Brace Jovanovich.

Calendar

Baum, A., & Baum, J. (1962). *One bright Monday morning.* New York: Random House.

Carle, E. (1985). *The very hungry caterpillar.* New York: Greenwillow Books.

Fisher, L. E. (1987). *Calendar art.* New York: Four Winds Press.

Goennel, H. (1986). *Seasons.* Boston: Little, Brown.

Heit, R. (1969). *The day that Monday ran away.* New York: Lion Press.

Holabird, K. (1989). *Angelina's birthday surprise.* New York: Clarkson N. Potter.

Kraus, R. (1987). *Come out and play, little mouse.* New York: Greenwillow Books.

Lyon, G. E. (1985). *Father time and the day boxes.* New York: Bradbury Press.

Schulevitz, U. (1967). *One Monday morning.* New York: Scribner's.

Sendak, M. (1962). *Chicken soup with rice.* New York: Harper & Row Publishers.

Sharmat, M. (1983). *The seven sloppy days of phineas pig.* San Diego, CA: Harcourt Brace Jovanovich.

Counting Books

Adams, P. (1973). *There was an old lady who swallowed a fly.* Sunburg, MA: Playspaces International.

Allbright, V. (1985). *Ten go hopping.* London: Faber and Faber.

Anne, M. (1975). *Anno's counting book.* New York: Thomas Y. Crowell.

Archanbault, J. (1989). *Counting sheep.* New York: Henry Holt.

Bang, M. (1983). *Ten, nine, eight.* New York: Greenwillow Books.

Blumenthal, N. (1989). *Count-A-Saurus.* New York: Four Winds Press.

Carle, E. (1968). *1, 2, 3 to the zoo.* New York: William Collins.

Keats, E. J. (1972). *Over in the meadow.* New York: Four Winds Press.

Giganti, P. (1988). *How many snails?* New York: William Morrow & Co.

Haskins, J. (1987). *Count your way through China.* Minneapolis, MN: Caraolrhoda Books.

McGrath, B. B. (1994). *M & M counting book.* Watertown, MA: Charlesbridge Publishing.

McMillan, B. *Counting wildflowers.* New York: Lothrop, Lee and Shepard.

Ockenga, S., & Dolittle, E. (1988). *World of wonders - A trip through numbers.* Boston: Houghton Mifflin.

O'Keefe, S. H. (1989). *One hungry monster.* Boston: Little, Brown.

Orinca, R., & Argent, K. (1985). *One wolly wombat.* Brooklyn, NY: Kane/Miller.

Owen, A. (1988). *Annie's one to ten.* New York: Alfred A. Knopf.

Tafuri, N. (1984). *Have you seen my duckling?* New York: Greenwillan Books.

Testa, F. (1982). *If you take a pencil.* New York: Dial Press.
Zavlasky, C. (1980). *Count on your fingers African style.* New York: Thomas Y. Crowell.
Ziner, F. (1962). *Counting carnival.* New York: Coward, McCann & Geoghegan.

Fractions

Emberley, E. (1984). *Picture pie.* Boston: Little, Brown.
Holl, A. (1967). *The runaway giant.* New York: Lothrop, Lee & Shepard.
Khalsa, D. D. (1989). *How pizza came to Queens.* New York: Clarkson N. Potter.
MacDonald, E. (1989). *Mr. Budger's birthday pie.* New York: Dial Books for Young Readers.
Matthews, L. (1979). *Gator pie.* New York: Dodd, Mead.
McMillan, B. (1991). *Eating fractions.* New York: Scholastic.
Moncure, J. B. (1988). *How many ways can you cut a pie?* Mankato, MN: Child's World.

Geometric Shapes

Carle, E. (1983). *The secret birthday message.* New York: Thomas Y. Cromwell.
Fisher, L. E. (1986). *Look around! A book about shapes.* New York: Harper and Row.
Gundersheimer, K. (1986). *Shapes to show.* New York: Harper and Row.
Holland, P. (1984). *Looking at logo.* New York: Macmillan.
Kightley, R. (1986). *Shapes.* Boston: Little Brown.
Newth, P. (1981). *Roly goes exploring: A book for blind and sighted children, in Braille and standard type, with pictures to feel as well as to see.* New York: Philomel Books.
Pluckrose, H. (1986). *Think about shapes.* New York: Franklin Watts.
Thompert, A. (1990). *Grandfather Tang's story.* New York: Crown Publishers.

Measurement

Anno, M. (1983). *Anno's math games.* New York: Philomel Books.
Arnold, C. (1984). *Measurements.* New York: Franklin Watts.
Baynton, M. (1987). *Tifty and the great race.* New York: Crown.
Briggs, R. (1970). *Jim and the beanstalk.* New York: Coward, McCann and Geoghegan.
Kellogg, S. (1976). *Much bigger than Martin.* New York: Dial Press.
Kennedy, R. (1975). *The contests at cowlick.* Boston: Little, Brown.
Myller, R. (1962). *How big is a foot?* New York: Atheneum.
Simion, S. (1986). *The largest dinosaurs.* New York: Macmillan.
Simion, S. (1982). *The smallest dinosaurs.* New York: Crown Publishers.

Multiplication and Division

Froman, R. (1978). *The greatest guessing game.* New York: Thomas Y. Crowell.
Giganti, P., Jr. (1992). *Each orange had 8 slices.* New York: Greenwillow Books.
Hutchins, P. (1986). *The doorbell rang.* New York: Greenwillow Books.

Origami

Churchill, E. R. (1989). *Fast and funny paper toys you can make.* New York: Sterling Publishing.
Corwin, J. H. (1988). *Papercrafts.* New York: Franklin Watts.
Nakamo, K. (1985). *Easy origami.* New York: Viking Penguin.
Phillips, J. (1972). *Right angles. Paper-folding geometry.* New York: Thomas Y. Cromwell.
Sakata, H. (1986). *Origami.* New York: Harper and Row.
Sarasas, C. (1964). *The ABC's of origami.* Rutland, VT : Charles E. Truttle.
Tofts, H. (1989). *The 3-D paper book.* New York: Simon and Schuster. Books for Young Readers.

Patterns

Ernst, L. (1983). *Sam Johnson and the blue ribbon quilt.* New York: Lothrop, Lee & Shepard.

Gardner, B. (1984). *The look again, and again, and again, and again book.* New York: Lothrop, Lee & Shepard.

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Langstaff, J. (1984). *Oh, a hunting we will go.* New York: Altheneum.

Lobel, A. (1979). *A treeful of pigs.* New York: Greenwillow.

Martin, B., Jr., & Carle, E. (1983). *Brown bear, brown bear, what do you see?* New York: Henry Holt.

Martin, B., Jr., & Carle, E. (1991). *Polar bear, polar bear, what do you see?* New York: Henry Holt.

Polushkin, M. (1978). *Mother, mother, I want another.* New York: Crown.

Probability and Statistics

Frederique & Papy. (1971). *Graph games.* New York: Thomas Y. Crowell.

Linn, C. (1972). *Probability.* New York: Thomas Y. Crowell.

Nozaki, A., & Mitsumasa, A. (1985). *Hat tricks.* New York: Philomel Books.

Time

Burningham, J. (1987). *John Patrick Norman McHennessy-The boy who was early late.* New York: Crown Publishers.

Carle, E. (1977). *The grouchy ladybug.* New York: Philomel.

Delacre, L. (1989). *Time for school Nathan!* New York: Scholastic.

Douglas, B. (1985). *The chocolate chip cookie contest.* New York: Lothrop, Lee & Shepard.

Gerstein, M. (1989). *The sun's day.* New York: Harper & Row.

Goennel, H. (1988). *My day.* Boston: Little, Brown.

Grossman, B. (1990). *The guy who was five minutes late.* New York: Harper & Row.

Maestro, B. (1984). *Around the clock with Harriet.* New York: Crown.

McMillan, B. (1987). *Time to.........* New York: Lothrop, Lee & Shepard.

Murphy, J. (1986). *Five minutes peace.* New York: G.P. Putnam's Sons.

Quality Literature to Teach Science

Air and Water

Allen, P. (1987). *Who sank the boat?* Crystal Lake, IL: Rigby Education.

Bloome, E. (1971). *The air we breathe.* Garden City, NY: Picture Book Studio.

Bright, R. (1983). *Georgie and the runaway balloon.* Garden City, NJ: Doubleday.

Burningham, J. (1970). *Mr. Gumpy's outing.* New York: Henry Holt & Co.

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Gibbons, G. (1983). *Boat book.* New York: Holiday House.

Keats, E. J. (1963). *Whistle for Willie.* New York: Viking Press.

Lloyd, P. (1982). *Air.* New York: Dial Books.

Nodset, J. L. (1970). *Who took the farmer's hat?* New York: Scholastic Book Services.

Rius, M., & Parramon, J. M. (1987). *Life in the air.* Woodbury, NY: Barron's.

Schulevitz, U. (1969). *Rain rain rivers.* New York: Farrar, Straus and Giroux.

Wyler, R. (1986). *Science fun with toy boats and planes.* New York: Simon & Schuster.

Animal Life

Barrett, J., & Barrett, R. (1984). *Animals should definitely not wear clothing.* New York: Atheneum.
Berger, G. (1987). *Sharks.* New York: Doubleday.
Brennan, J., & Keaney, L. (1987). *Zoo day.* Minneapolis, MN: Carolrhoda.
Carle, E. (1989). *Animals, animals.* New York: Philomel Books. (Poetry)
Carle, E. (1985). *The very busy spider.* New York: Philomel Books.
Craig, J. (1990). *Amazing world of spiders.* Mahwah, NJ: Troll Associates.
Cohen, M. (1971). *Best friends.* New York: William Morrow.
Cohn, D. (1987). *Dinosaurs.* New York: Doubleday.
Cole, J. (1986). *Hungry, hungry, sharks.* New York: Random House.
DePaola, T. (1990). *Little Grunt and the big egg.* New York: Holiday House.
Dunn, P. (1985). *Animal friends.* New York: Random House.
Epstein, S., & Beryl. (1989). *Bugs for dinner? The eating habits of neighborhood creatures.* New York: Macmillan.
Florian, D. (1986). *Discovering frogs.* (1986). New York: Charles Scribner's Sons.
Guarino, D. (1989). *Is your mama a llama?* New York: Scholastic.
Heller, R. (1982). *Animals born alive and well.* New York: Grosset & Dunlap.
Heller, R. (1981). *Chickens aren't the only ones.* New York: Grosset & Dunlap.
Hoffman, M. (1985). *Animals in the wild: Elephant.* New York: Random House.
Keats, E. (1989). *Pet show.* New York: Macmillan.
Lionni, L. (1976). *A color of his own.* New York: Pantheon.
Mayer, M. (1989). *What do you do with a kangaroo?* New York: Scholastic.
McCloskey, R. (1968). *Blueberries for Sal.* New York: Viking Press.
McCloskey, R. (1969). *Make way for ducklings.* New York: Viking Press.
Parsons, A. (1990). *Amazing snakes.* New York: Alfred A. Knopf.
Rinard, J. (1985). *Helping our animal friends.* Washington, DC: National Geographic Society.
Roe, R. (1985). *Baby animals.* New York: Random House.
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Chapter 23

Math/Lit Kits: Simple Yet Rich Activities Which Engage Families in Important Mathematics in a Playful Way

Diana Stevenson & Cyndi Broyer

"What can I do to help my child at home with mathematics and reading?" Teachers and librarians hear this question from parents who want something simple, effective, and enjoyable to help their children after a day at work. Good teachers understand that parents are their children's first teachers. At the K-3rd grade stage it is vital to maintain and build on this understanding by providing parents with opportunities to help their children in a meaningful way which will complement schoolwork. The research on parent involvement indicates that children benefit greatly when parents and teachers support each other in their respective roles (Swick, 1991).

Most parents understand the proven value of reading regularly with their children and many try to have a regular story time (Topping & Wolfendale, 1985). However, it is not so easy to express in simple terms what parents can do to enhance mathematics development in their young children. Many parents, especially mothers, do not consider themselves to be "good at math." This is a poor stereotype to model, especially for little girls (Schwartz, 1992). For busy parents, many of whom are working outside the home, a children's book packed conveniently in a bag with manipulative pieces and simple instructions for a game related to the book is easy and non-threatening to use. The kits build on the knowledge parents already have about enhancing literacy skills.

By creating Math/Lit kits, teachers are able to offer parents a book to read as well as a game based on the mathematics concepts embedded in the text of the book. Games allow for social interaction within rules. This gives children practice and confidence in their ability to work things out for themselves (Kami, 1985). Making the kits can be an enjoyable collaborative project that involves teachers, library staff, parent volunteers, and students. Once a core collection is put together and begins circulating, further titles and ideas for related activities can be worked up into kits and added to the collection as time or money permit.

Selecting Books for a Math/Lit Kit project

Professional books and periodicals are used to identify books that may contain mathematics concepts. The school library media specialist has many selection tools available as well as expertise to help identify suitable titles. Mathematics materials catalogs frequently have sections on the mathematics/literature connection and can be a useful source of ideas for books with embedded mathematics concepts.

A list of titles addressing a variety of concepts needs to be compiled in order to collect as many books as possible for review. An annotated bibliography of books presented in this chapter is presented at the end of the chapter. Books suitable for kits can be traditional counting books where number, symbol, name, and amount are depicted such as *Moja Means One* (Feelings, 1971) or *Ten, Nine, Eight* (Bang, 1983). Other non-fiction books that address mathematics concepts directly, such as Ehlert's (1989)*Color Farm* (geometry) or McMillan's (1991) *Eating Fractions,* make excellent books with which to start a collection as activities are easy to produce

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to support the concepts. Fiction or storybooks may need more work as the concepts need to be articulated clearly so that the activities reflect the mathematics embedded. For example, *Two of Everything* (Hong, 1993), taken on the level of the story, is a delightful Chinese folk tale about a couple who finds a magic pot that doubles everything that is put into it. When they put in a purse full of coins, they retrieve two purses and double the amount of coins. Like King Midas, the couple soon finds that there is a problem with having such power and the story is about the resolution of this problem. However, embedded in the story are the concepts of doubling and multiplying by two. Including instructions with the book for an activity, as well as manipulatives to carry out the activity, gives the child ways of practicing use of this concept.

The simplest way of creating a core collection of titles is to pull as many of the books available from the classroom or school library. Collaboration with other teachers and library personnel is invaluable for ideas and resources.

When buying specifically for a Math/Lit Kit project with budgeted funds, a decision needs to be made whether to buy paperback or hardback books. This will depend on the budget and personal philosophy. Hardback books are durable but costly; paperback books may not last as long but are cheaper, allowing for a larger more varied collection.

Creating the Activities to Go with the Books

Activities may closely follow the story line through reenactment with manipulatives, or activities may reinforce embedded mathematics concepts by providing practice in related skills. For example, *Ten, Nine, Eight* is a reverse counting book which tells of a small child preparing for bedtime. She starts by cleaning "10 small toes" and ends up as "1 big girl all ready for bed." This book is about subtraction and the idea of one less. It is also about sequencing in the countdown of activities in preparation for bedtime.

A very easy activity for parent and child is simply to act out the story as it is being read, using counting pieces or counters such as beans or pasta to represent the objects counted in the story. Even at this level, the social interaction and conversation about "one less" that takes place is a rich teaching and learning moment for the parent and child.

Related activities can be suggested to extend out from the book. For *Ten, Nine, Eight,* a game with counters and a container, allows subtraction practice. The child is shown a number of counters, then the counters are covered with the container. The parent slips a hand under the edge and pulls out some counters and puts them on the upturned tub. The child tells how many counters are now under the tub.

This can be yet further extended by suggesting to the parent the value of helping the child come to know number combinations for various amounts. By starting with three counters, all the combinations of three can be interactively explored (Figure 23.1).

Working with *Two of Everything* also involves a story-based game and a reinforcing extension activity. The concept of doubling and multiplying by two can be reenacted by using a container for the magic pot, some counters or play coins, and small bags for purses. A simple game with these objects allows the child to become confident in understanding "twice" and "two times" as the parent talks the child through the activity. Extending this skill to include the idea of doubling can be achieved by adding a board game (Kaye 1987) that helps the child understand and remember double equations, 2+2, 3+3, 4+4, and so on.

Manipulatives for these activities can be inexpensive, easily replaceable items like pasta, beans, poker chips, dice, and playing cards. Recycled materials such as buttons, ribbons, bread tags, and bottle caps are also useful. Colleagues may be able to share resources with manipulatives from the classroom. Parents may have game pieces from used commercial games that can be adapted for use with the kits.

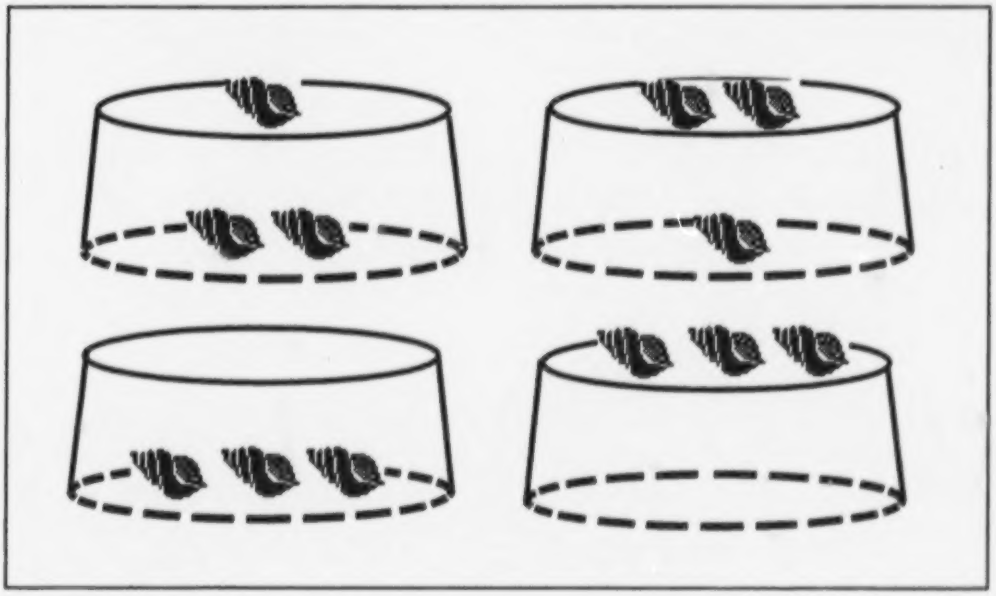

Figure 23.1 *All number combinations with 3 shell counters*

Writing the Instructions

Writing the instructions is probably the most labor intensive part of this project. Each book requires a set of clear instructions about the activities. These instructions should be mounted on a card and laminated with transparent plastic. It is helpful to create a master or template for the instruction card so that the format remains consistent for all the kits (Figure 23.2).

After identifying the title and author, the mathematics skill in the book is identified. This is to validate the mathematics contained in the book for parents and to engage them as "mathematics" teachers of their children. Then the instructions for the activities need to be written in simple language that a tired parent or older sibling can easily understand (Figures 23.3 and 23.4).

The instructions also need to be field-tested to make sure they are valid. Parents become very frustrated if the instructions are flawed or missing a vital step. Field testing can be done as a project with children in older grades. Sixth graders make excellent testers, identifying flaws in a game or activity as well as suggesting useful extensions.

Finally, adding a cross-reference to another title that contains similar or related concepts is useful for both parents and teachers seeking further reinforcement.

Putting the Math/Lit Kits Together

The bags need to be of sturdy clear plastic so that parts can be checked quickly. Heavy duty plastic freezer bags are a good value. Media hanger bags (available from library supply catalogues) with a hook to hang the kits and a handle for carrying are good for displaying the

TITLE: AUTHOR

The math skill(s) that this book relates to is/are...

An extension activity would be.....

If you would like to know more about this kind of activity read:

TITLE: AUTHOR:

Figure 23.2 *Instruction Card Master*

TITLE: TEN, NINE, EIGHT AUTHOR: BANG

The math skills that this book relates to are subtraction (one less) and sequencing.

An extension activity would be to follow the story using the shells as counters, using the words "one less" as you talk with your child.

Next try a subtraction game. Show your child 3 shells. Cover the 3 shells with the plastic tub. Slip your hand under the edge and pull out some shells and put them on the upturned tub. Ask your child to tell how many shells are under the tub now.
Once your child has mastered the combinations of 3 go on to 4. The goal is to help the child to "know" confidently how many shells are hidden by spending time on number combinations. Stay with one amount of shells each day or time and explore all the combinations for that amount. The next time switch to a different number and explore the combinations for that number.

If you would like to know more about this kind of activity read:

TITLE: ROLL OVER : A COUNTING SONG AUTHOR: PEEK

Figure 23.3 *Instructions for Ten, Nine, Eight*

TITLE: TWO OF EVERYTHING AUTHOR: HONG

The math skills that this book relates to are doubling, multiplying by two.

Extension Activity for two people:- Each person gets 10 coins and a purse. Use a saucepan as a pot. Put some coins in a purse and pop it into the pot. The child checks to see how how many coins there are in the purse, then puts the same amount into his/her purse and tosses it into the pot. Ask your child how many coins total are now in the pot. Open the purses and check the answer.
Try to use the words "twice" and "two times" as well as "double" as you talk with your child. (You need to use the two purses to model the "2 times" concept.)
Use the board game included to play a doubles game. Advance your game piece twice or double the amount rolled on the dice.

If you would like to know more about this type of activity read:

TITLE: BUNCHES OF BUNNIES AUTHOR: MATHEWS

Figure 4 *Instructions for "Two of Everything"*

kits tidily. They are more expensive than the freezer bags, but will last longer especially if the bottom is reinforced with clear wide tape.

The book should be packed along with the instructions on a card and appropriate manipulative pieces in the bag (Figure 23.5). Small pieces can be kept together in a plastic bag or recycled tub with a lid. Marking the parts with indelible marker and identifying them as part of a kit helps parents and children put the kit back together after playing the games.

A "parts" list should be attached to the bag with clear tape so it can be easily seen for quick checking when the kit is returned (Figures 23.6 and 23.7).

Keeping Track of the Math/Lit kits

A simple circulation system needs to be established to track the kits as they are borrowed. An index card with the name of the book should be attached to the instruction sheet or put in a book pocket inside the book. When a kit is checked out, the borrower's name is written on the title card and kept in a small file box.

The kits can be kept neatly stacked in plastic dish tubs or hung from a rope by clothespins. Useful racks can often be obtained from stores that are remodeling.

Maintaining the Math/Lit Kits

It is to be expected that kits will occasionally be returned with missing parts. Duplicates and replacements should be kept on hand so that missing parts can be quickly replaced. A master file of instructions and parts lists is invaluable when a kit comes back with the instructions or the parts list missing. Looking after the kits can be a job for parent volunteers or older students.

Introducing the Math/Lit Kits

An "open house" or "Family Mathematics" session is an ideal time to introduce the kits to parents. Modeling how to use the kits helps parents become effective teachers of their children.

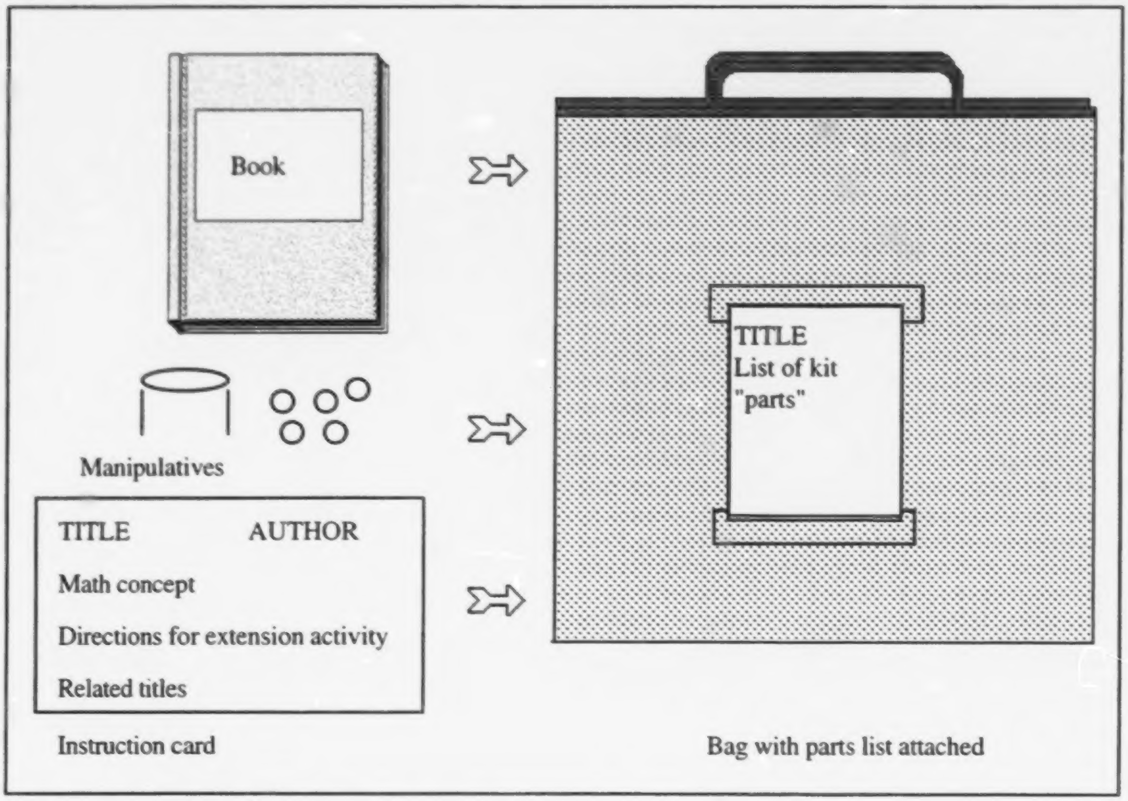
Book
Manipulatives
TITLE AUTHOR
Math concept
Directions for extension activity
Related titles
Instruction card
TITLE
List of kit
"parts"
Bag with parts list attached

Figure 23.5 *Putting the Kit Together*

TEN, NINE, EIGHT

THIS KIT CONTAINS :

1 BOOK
1 plastic tub
1 pack of approx 24 pasta shells

Figure 23.6 *Parts list for "Ten, Nine, Eight"*

TWO OF EVERYTHING

THIS KIT CONTAINS :

1 BOOK
2 purses
25 play coins
1 game board and cards
1 die

Figure 23.7 *Parts list for "Two of Everything"*

It is important to stress to them the value of talking with the child about what they are doing together while they are interacting (Mokros, 1996).

This is a good project for parent volunteers to help with in the creation and maintenance as it helps them understand how children learn mathematics and empowers them to share their knowledge with other parents. For parents who may regard themselves as "no good at math," this can be a valuable experience.

Other Ways of Using the Math/Lit Kits

The kits may be used with "buddy" classes where an older grade works with a younger "buddy" grade. Older children can be encouraged to check the kits out for use at home with younger siblings. Upper elementary students are frequently full of suggestions for new or improved activities to go with the books. This can be developed into a language arts lesson where groups of students are asked to create a mathematics game to go with a picture book, then asked to write clear directions for their game.

This project has been used as an inservice workshop. Teachers are asked to select a book from a collection available at the workshop or to bring along one of their classroom favorites. Their task is to identify the mathematics concepts in their book, then to create an activity to go with the book making manipulatives from recycled pieces provided. The activities are written as instructions to be tested by the group. Modifications and adjustments to the instructions are made as needed, and parts lists are added. Finally, all the instructions and lists are compiled into a hand book for each participant to take back to the classroom.

Conclusion

Math/Lit Kits demonstrate in a tangible way the relationship between language and mathematics. They encourage and empower parents to share rich language experiences with their children who will, as a result, become confident learners in school. Parents and teachers involved in a meaningful partnership can provide children with ongoing learning experiences in and out of school. This continuity encourages children to become lifelong learners.

About the Authors

Diana Stevenson, M.Ed., is a library media generalist working at the Pine Tree Elementary School in Center Conway, NH. She collaborates with Ms. Broyer on projects that integrate mathematics, science, language arts and technology. They present various workshops on these topics at professional conferences in New England. "Math/ Lit Kits" was presented at the NCTM national conference in Boston in 1995.

Cyndi Broyer, B.S., is the elementary mathematics resource coordinator for the Conway, NH, School District. She conducts district inservice training as well as teaching graduate level pre-service mathematics in the Extended Teacher Education Program (ETEP) for the University of Southern Maine.

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Griffiths, R., & Clyne, M. (1991). *Books you can count on.* Portsmouth, NH: Heinemann.

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Lewis, B. A., & Long, R. (1993). Fostering communication in mathematics using children's literature. *Arithmetic Teacher 40*(8), 470-473.

Mokros, J. (1996). *Beyond facts and flash cards: Exploring math with your kids.* Portsmouth, NH: Heinemann.

Schwartz, W., & Hanson, K. (1992). *Equal mathematics education for female students.* New York: ERIC Clearinghouse on Urban Education. (ERIC Document Reproduction No. ED 344 977)

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Topping, K., & Wolfendale, S. (1985). *Parental involvement in children's reading.* East Brunswick, NJ: Nichols.

Whitin, D., & Wilde, S. (1992). *Read any good math lately?* Portsmouth, NH: Heinemann.

Annotated Bibliography of Children's Books

Bang, M. (1983). *Ten, nine, eight.* New York: Greenwillow.
A reverse counting book and bedtime story, each number bringing the day to a close from ten toes that need to be washed to one girl ready for bed. Subtraction and sequencing.

Briggs, R. (1970). *Jim and the beanstalk.* New York: Putnam.
In a new take on a familiar tale, Jim climbs the beanstalk to find that the old giant needs to be measured for glasses, a wig, and false teeth. Measurement and proportion.

Clement, R. (1991). *Counting on Frank.* Milwaukee, WI: Stevens.
A boy uses his imagination to estimate fantastic amounts of familiar objects. Estimating, measuring.

Ehlert, L. (1989). *Color farm.* New York: Harper.
A wordless picture book with shapes die-cut into the pages, providing a playful interactive way of creating the farm animals with shapes by turning the pages. Geometry and spatial reasoning.

Feelings, M. (1971). *Moja means one.* New York: Dial.
This is an East African counting book that uses Swahili number words to count people and objects pictured in an African context. Counting and sequencing.

Hong, L. T. (1993). *Two of everything.* Niles, IL: Whitman.
A Chinese folk tale about a magic pot that doubles everything that falls into it. Doubling, multiplying by two.

Lottridge, C. (1986). *One watermelon seed.* New York: Oxford.
Using a gardening theme for this picture book, the author demonstrates how each seed or plant produces ten times its number in fruit or vegetables from one watermelon seed producing 10 watermelons all the way to 10 corn seeds producing 100 ears of corn. Place value.

McMillan, B. (1991). *Eating fractions.* New York: Scholastic.
wo children and their dog share a meal which can be cut into halves, thirds, and fourths. This book shows how parts make a whole. Recipes are included with the book. Fractions.

Pinczes, E. (1993). *One hundred hungry ants.* Boston: Houghton.
In this story told in verse, the hundred hungry ants try to get to the picnic faster by traveling in different formations suggested by the littlest ant. Factors of 100, conservation.

Reid, M. (1990). *The button box.* New York: Dutton.
A small boy playing with his grandmother's button box sorts buttons according to the ways buttons play a part in his life. Sorting.

Weston, M. (1992). *Bea's four bears.* New York: Clarion.
Bea takes her four different teddy bears for a walk, loses them along the way and rediscovers them in amusing fashion on the way back. Addition, subtraction and the concept of "zero."

Young, E. (1992). *Seven blind mice.* New York: Scholastic.
This picture book tells how seven differently colored mice take a week to solve a puzzle together. Ordinals (1st, 2nd....) are cleverly linked with the days of the week and color recognition skills. Ordinals, sequencing, time.

Chapter 24

Using Community Resources: Integrating Science, Mathematics, and Social Studies on a Primary Field Trip to the Grocery Store

Michael L. Bentley, Stephen Bloom, & Virginia Reynolds

> "This banana has a sticker on it that says it is from Mexico."
>
> "I found some potatoes that came from Idaho."
>
> "The label shows that I get more peanut butter for my money if I buy the bigger jar."
>
> "The core of the apple looks like a five pointed star."
>
> "These 2 loaves of bread weigh the same, but this one is smaller. It must be made out of heavier ingredients!"

Field site experiences challenge and extend and provide real-world contexts for learning. These comments, made by primary grade students following a field trip to a local grocery store, are indicative of the rich, interdisciplinary connections that can be developed by young children when thoughtfully designed field site experiences are included in the curriculum. These children are constructing meaningful relationships among concepts and skills within and among mathematics, science, social studies, and language arts.

Class experiences outside of the school enable children to recognize the relevance of their school studies to the world beyond the classroom walls. Moreover, field trips can take advantage of the dominant kinesthetic learning modality of primary aged children. As Michael Grinder (1991, p. 6) aptly puts it, "Teachers at this level know that their students understand reality by touching, smelling, tasting, pushing, shoving, banging and taking apart their world."

In this chapter we offer an example of a particular community resource for a primary field trip, the grocery store or supermarket. We will look at how this commonly found community resource can provide integrative learning opportunities for young children. We begin by considering the educational value of learning experiences outside of school and then present a detailed example of how a field trip to the grocery store can be organized to integrate instruction across the primary curriculum.

Research on Field Experiences

Field site experiences, or simply *field trips*, can be broadly defined as "any journey taken under the auspices of the school for educational purposes" (Sorrentino & Bell, 1970, p. 233). Senta Raizen and A.M. Michelson (1994, p. 48) declare that, "Viewing the world beyond the school as part of students' learning community is critical for effective science teaching." As we see it, viewing the world beyond the classroom as part of children's learning community is critical for effective teaching in the other school subjects as well. Incorporating field trips in the curriculum can address the need to make educative experiences come alive and to promote a sense of community (Dewey 1900, 1938; Dewey & Dewey, 1915). Field trips also can be an effective way of using the project approach with young children (Katz & Chard, 1989; Edwards & Springate, 1993).

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Educators highly value the positive attitudes and cognitive learning that children often develop as outcomes of field trip experiences (Falk & Balling, 1979). Teachers include such experiences in the curriculum for a number of reasons, including a desire for a change of pace, as a means for enriching the curriculum, and for the social experience for children (Rennie & Elliott, 1991; Gottfried, 1980).

Education in the U.S. at the end of the century is in the midst of a standards-based reform movement. Many of the standards documents (NCTM, 1989, 1991, 1995; NCSS, 1994; NRC, 1996) can be cited to support community-based education. The Geography Education Standards (GESP, 1994) lists 18 categories of skills and knowledge of the geographically informed person. Such a person knows and understands, for example:

- How to use maps and technologies to acquire, process, and report information from a spatial perspective.
- How to analyze the spatial organization of places.
- The physical and human characteristics of places.
- The patterns and networks of economic interdependence.

As we shall see below, each of these areas can be addressed by activities conducted on a class trip to the grocery store.

The Interactive Experience Model

Drawing on the current knowledge of how people use informal educational institutions, e.g., museums, Falk and Dierking (1992) proposed their Interactive Experience Model, which we have adapted in the graphic shown in Figure 24.1. Falk and Dierking conceptualize the child's experience on a visit to a field site as an interaction among three contexts: (a) personal, (b) social, and (c) physical. We can see from the Interactive Experience Model that the outcomes a child attains depend on that child's own personal backgrounds of knowledge, experiences, skills, motivations, and desires; the interactions with peers and adults during the visit; and the physical environment created by the exhibits and their surroundings.

This model provides a framework for examining the outcomes of field trips in a range of educational settings, including common community resources such as the grocery store. Further it suggests the idea that outcomes from field trips are strongly related to what occurs before, during, and after the field trip. The task for the classroom teacher is to integrate the personal, social, and physical contexts so that the field trip experience is coherent and meaningful for the children in the class.

The cognitive, affective, and social learnings which children acquire through field experiences are affected by how the field trips are organized, planned, conducted, and connected to the classroom (Rennie & McClafferty, 1995). In discussing the use of orienting activities in connection with field trips to science centers, Rennie and McClafferty (1995) note benefits for the discussion of purposes for the field trip, showing pictures of the venue, incorporating time for student exploration of the exhibits, and providing guide materials. The use of such structuring activities before, during, and after the visit can increase learning, create a context for the experience, and link it with the classroom (Finson & Enochs, 1987; Koran, Lehman, Shafer, & Koran, 1983; Wollins, Jensen, & Ulzheimer, 1992).

In considering potential outcomes of a field trip, teachers should consider more than just the demonstrable cognitive gains. Price and Hein (1991) define "educationally effective programs as those in which products are not emphasized, inquiry is sparked, open-ended questions are generated, and students actively participate and appear involved" (p. 510). Wollins, Jensen, and Ulzheimer (1992) found that third graders' most powerful memories of visits to museums were related to affective or emotional content of the experiences and that

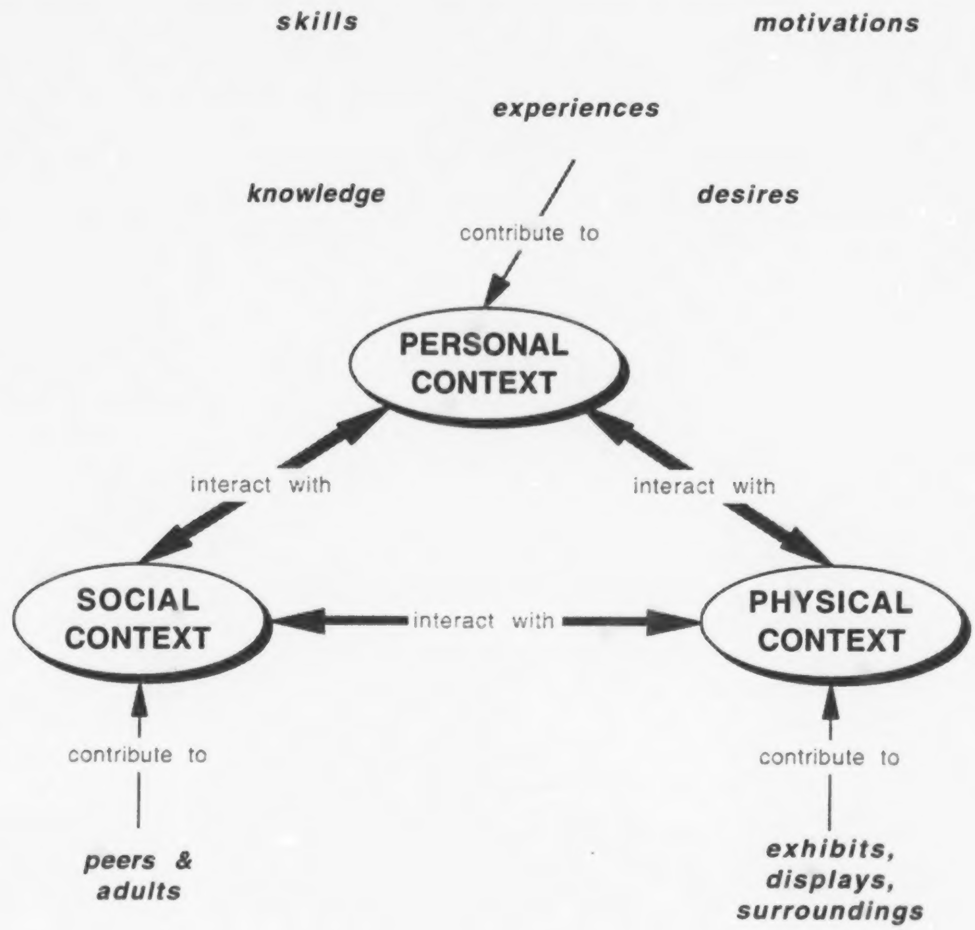
skills
motivations
experiences
knowledge
desires
contribute to
PERSONAL CONTEXT
interact with
interact with
SOCIAL CONTEXT
interact with
PHYSICAL CONTEXT
contribute to
contribute to
peers & adults
exhibits, displays, surroundings

Figure 24.1 *An Adaptation of Falk and Dierking's Interactive Experience Model (1992)*

these memories were often both unique to the child and not the intended goals of the museum educator or the teacher. This finding, in light of the importance of both cognitive and affective aspects of learning presented in Falk and Dierking's Interactive Experience Model, should be pondered by teachers as they think through the use of field trips as educative experiences for their students.

Summary of the Research on Field Trips as School Experiences

The research suggests that students enjoy field trips, but that the amount and nature of the cognitive and affective learnings vary. The personal, social, and physical contexts of a field trip are factors that affect the outcomes of field trips, as implied in Falk and Dierking's Interactive Experience Model. Factors such as students' familiarity with the setting; prior knowledge; the match between the cognitive levels of students and the activities in which they engage before,

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during, and after the field trip; the nature and amount of structure for the field trip; and the social aspects of the field trip can influence student learning. Many of these factors can be influenced by teacher's planning and behaviors. Therefore it seems that the teacher can greatly influence the degree and impact a field trip makes in the education of his or her students.

Creating an Environment for Inquiry

If the personal, social, and physical contexts of a field trip are factors that affect what is learned, what can the teacher do to increase the odds of student learning? These contexts for learning can be enhanced by creating an environment of inquiry. To create an inquiry-oriented atmosphere, the teacher can model the exploratory and investigative spirit and can help children translate their interests and curiosity into questions to be answered and problems to solve.

What is Inquiry?

According to the recently released National Science Education Standards (NRC, 1996, p. 23), inquiry "refers to the activities of students in which they develop knowledge and understanding of scientific ideas as well as an understanding of how scientists study the natural world." In science, inquiry refers to the multiple ways scientists study nature and propose explanations based on what counts as evidence in their work. Inquiry teaching, then, is an approach that enables children to explore ideas and conduct investigations in a scientific manner. When children learn through inquiry they develop their concepts of the most important content. They also develop an understanding of the parts of a pattern of inquiry. Learning through inquiry also includes developing the habits of mind and skills of a researcher.

The Grocery Store as a Community Resource for Inquiry

Many local community sites can provide ideal contexts for young children to become engaged in inquiry. The school subjects become naturally integrated in the child's mind through inquiry in a materials-rich setting. This integration is suggested in Figure 24.2. Such a place is the local grocery store or supermarket. Supermarkets and grocery stores are available to teachers in almost every community. It requires no special talent to engage primary level children in real-world investigations in such a setting. What's more, children can learn useful information they can share with their families, as it is likely they will accompany their caregivers to the grocery store on many subsequent occasions.

Private businesses are not typically considered as suitable field trip sites for young children, but Raizen and Michelson (1994, p. 48) point out that, "businesses... demonstrate how...knowledge is developed and used and exemplify the variety of careers available to students." Businesses also demonstrate the use of mathematics in the world of work, as well as important principles of economics, and the role of communications and social relations.

Planning and Activities for the Field Trip

Organizing the Field Trip

A general principle is that a field trip should be contextualized within a broader unit of study. For the primary grades, there are many possible units within which a field trip to the grocery store would be a curricular enhancement. For example, the *community* is frequently a unit focus in primary social studies. Another primary social studies focus is multiculturalism, which also has ample grocery store connections. In science, *plants* and *animals* are typical primary units and plant and animal products are the 'bread and butter' of the grocery store. In both science and mathematics, classifying objects and measurement are frequently taught at this level. These and many other connections can be found at the grocery store.

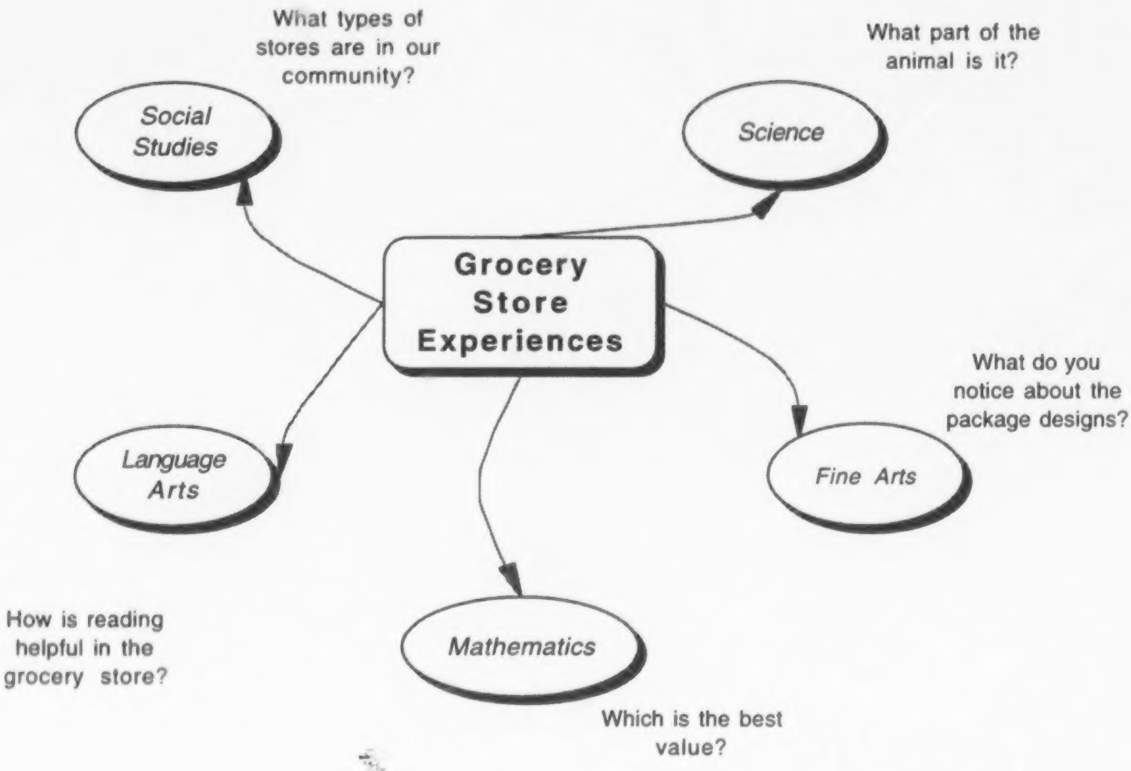
What types of stores are in our community?
What part of the animal is it?
Social Studies
Science
Grocery Store Experiences
What do you notice about the package designs?
Language Arts
Fine Arts
How is reading helpful in the grocery store?
Mathematics
Which is the best value?

Figure 24.2 The grocery store can demonstrate the natural integration of the subjects.

The grocery store field trip can be the source for an activity series within a unit of study. Young children are always excited about exploring the world outside of school. For many young children, a class trip is a much anticipated event. The energy and excitement generated by such anticipation can spark the development of questions that can serve as foci for the class' investigations.

The teacher planning the trip should contact the grocery store manager ahead of time, request permission, and discuss the activities of the children for the visit. If the visit is approved at the school level and by the store, the manager can be contacted to confirm dates and time and discuss supervisory procedures. At this time the teacher can ask the manager to help with particular activities. For example, in the case of our grocery store trip, the butcher could have available a poster or chart showing the cuts of meat constituted into a whole and the produce person could have a list of vegetables at the store and information about where each was grown.

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Children will need a hard surface for recording their observations and data at the store. A simple clip board can be made from an 8.5 x 11 inch piece of cardboard cut from a carton, with a clothes pin attached to the top to hold the paper. Groups will need paper and pencils and any special tools needed for their investigations. Rulers, magnifying glasses, and hand-held calculators might be needed for some investigations. A thermometer would be needed if a group wanted to investigate the temperature range in the store. All the tools could be distributed to the inquiry groups when the class arrives at the field site. One child in each group could have the role of equipment supervisor.

The on-site time for young children, from our experience, should be planned for approximately one hour. Travel time to the grocery store will have to be added to that, but whenever possible, a local grocery store should be chosen. Thus, in most circumstances, the grocery store field trip activity can be accomplished in a half-day, which could be either the morning or afternoon (the grocery store manager is likely to prefer a time when the fewest customers are likely to be in the store).

When planning for the trip, the teacher should consider and prepare for potential hazards, for example, the need to walk across a busy intersection. Important safety reminders can be found in Figure 24.3.

Providing Structuring Activities

The teacher will need to plan carefully the larger unit of instruction so that the activities prior to the field trip enhance the learning potential. Orienting activities include discussing the purposes for the field trip, showing pictures of the field site, and providing guide materials, such as a site map (Rennie & McClafferty, 1995). Structuring activities before the visit can create a context for the experience and link it with the classroom (Finson & Enochs, 1987; Koran, Lehman, Shafer, & Koran, 1983; Wollins, Jensen, & Ulzheimer, 1992).

Working with children to create a guide to the site and a list of questions about topics to investigate is an important structuring activity. The guide can be based upon pictures of the site or, in our example, a map of the grocery store. As Lila James (1986-87, p. 32) has noted, "Very young children sometimes have difficulty formulating questions and they do like to tell stories about their experiences." A list of stimulus questions and investigations also might be prepared as a 'crib sheet' for the adult participants. Some examples of questions for a grocery store field trip are:

- What do you know about (product, category, etc.)?
- What different kinds of things are for sale in this section of the market?
- What (item) has been brought to this store from the greatest distance?
- Which one costs more? less?
- Which items cost about $1, $10, or more than $10?
- Which is the best value?
- Which has the most (peanut butter, etc.)? the least?
- Which packaged items weigh about 1 pound, 5 pounds, or 10 pounds?
- Where did it come from? How did it get here?
- What is it made of?
- How was it made?
- What part of a (plant, animal) is it?
- What does the (butcher, baker, produce person) do in his/her work?
- What tools do they use?

Field Trip Safety

A safe field trip is a well planned trip, where educational objectives are identified and the activities conducted are intended to achieve those objectives. When the children's' activities are well organized, the possibility of an accident is reduced. A few relatively simple precautions can help insure safety for all participants.

- Teachers should never take anything for granted where students are concerned and should always be alert for the unexpected.
- Additional responsible adults, known and approved by the school administration, should accompany the teacher on the trip.
- Parent permission should be solicited and received before a child is allowed to go on a field trip.
- A list should be sent home identifying the proper clothing to be worn and the necessary supplies to be taken on the trip.
- A first aid kit should be carried, and checked to see that essential first aid items are stocked.
- Trips must be well supervised. An experienced representative of the site or agency should be on hand for assistance (NSTS, 1977, 4-18).

Figure 24.3 *Safety reminders for local elementary school field trips*

Children can be divided into investigative groups prior to the visit. Each group can plan to investigate one or more 'learning stations' at the store. Figure 4 illustrates a number of departments typical for a grocery store or supermarket and some sample questions for investigation within those departments. After the orienting 'walkabout' activity at the store, groups may proceed to their designated 'learning station.' The adult participants can guide their group through a pre-arranged sequence of stations.

Pre-trip planning should also include planning the post-trip activities. The teacher should have a sense of the whole unit; the fit of the field trip; and all the activities, before, during, and after the trip. The pre- and post-visit activities help the children connect their experience with the content of the curriculum and make it their own.

Often field trips do not meet their educative potential. There are many reasons for this, including inadequate or inappropriate pre- and post-trip activities, and inadequate or inappropriate on-site activities. In our opinion, field trips can also fail because the teacher has not enabled an environment for inquiry.

Department/Section	Possible Inquiry Investigations
Dairy Products	Which of these items are natural foods for other animals? Which of these items are manufactured?
Produce	Which of these items can be grown in your community? Which items come from other communities?
Frozen Foods	How are frozen foods packaged? What information about the item can be found printed on the label?
Canned Goods	What is the typical sized can of food? What kinds of food are often found in cans?
Household Items	Which of these items are labeled as poisons? Where are they located on the shelves? Why?
Bakery Goods	What kinds of baked goods are in this section? How are cookies packaged?
Meat/Poultry/Fish	What items are parts of animals? Which items contain both bone and muscle?

Figure 24.4 *Sample Grocery Store Investigations.*

Sample Supermarket Learning Activities

Pre-Trip Activities

Pre-trip activities need to orient the children to the learning tasks of the trip and activate their prior knowledge. Some orienting activities with which we have had success are to have children discuss, first in small groups, then in whole class settings, questions like the following:

1. What types of grocery stores are in our community?
2. What do customers do in the grocery store?
3. What do grocery store employees do in grocery stores?
4. How might we see customers doing mathematics on our field trip?
5. How might we need to use our reading and writing skills when on the field trip?
6. What items might we see at the grocery store during this season that we wouldn't see during a different season?

As a way to further orient the children to the locations of various departments of the grocery store, a scaled-down version of the grocery store can be laid out in the classroom or a larger room in the school, e.g., gym, multi-purpose room. The completion of this project can be very beneficial, especially if this 'model store' is both large enough to allow the children to 'walk the aisles' and is arranged in a way that closely approximates the location of the departments in the grocery store, e.g., check out areas close to the front doors, meat/poultry/fish in the back of the store, canned goods on shelves separated by aisles.

As we noted above in relation to the Interactive Experience Model, the learning outcomes for the children result from an interaction between social, physical, and personal factors.

Motivation and desire to learn, which contribute to the personal aspect, can be enhanced by the pre-trip activities planned by the teacher. These activities will tap children's innate curiosity and help them form their own learning goals.

The teacher also can do much to encourage positive social communications. The social factor can be enhanced by the formation of inquiry groups before the trip. Below are some activities that help children prepare in such a way as to promote potential learning outcomes. Many of the activities suggested below serve multiple purposes, including to promote social cohesion and develop knowledge and thinking skills.

A popular strategy for explicating children's prior knowledge is the 'K-W-L' (Ogle, 1986). The teacher can begin the field trip sequence by having children express what they already know about supermarkets, what can be found there, what different kinds of work are done there, and so forth. By cueing, probing, and inviting elaboration, the teacher can help children extend their concepts. For example, children might list fruit and vegetables as things that can be found in the supermarket, but not be aware of the many different forms these items may take. The teacher can ask, *Which of these are fruits?* Children are likely to list a number of fresh fruits and vegetables. Inquiry groups can make a chart or web of the different fruits and vegetables they predict. At a post-trip learning center, the groups could be provided with an assortment of fruits and vegetables and asked to sort the fruits and vegetables and make a new chart. The groups will likely need a knife to cut open the fruits and vegetables in order to determine if seeds are found inside—the key difference between a fruit and a vegetable. The teacher can look for development in the chart as one means of assessment (see below).

The pre-trip discussion of fruits and vegetables could go further still. The teacher may need to help children realize that the supermarket also stocks preserved fruits and vegetables. The teacher can ask, *How can we keep food from spoiling?* Children might know that freezing preserves food. Other ways include canning, adding certain chemicals (preservatives), and drying the food. At the grocery store, children can investigate the variety of foods preserved in different ways. The groups can construct a chart listing the foods they found and the methods used to preserve them. Figure 24.55 shows an example of a completed table. It illustrates one way to answer the question, *How can we classify preserved foods?*

Related to the discussion that could arise about the kind of food in the grocery store, children also could investigate food additives among the ingredients of different items, like bottled fruit drinks or commercial breads or cereals. Some additives are there to preserve the food, while others enhance the color or aroma. Children participating in such an investigation might make a chart similar to Figure 24.55 as a way of ordering the additives they found in particular processed foods.

One way to excite children's thinking is to propose the class hold a food festival after the field trip. Children can work in teams to research recipes for one or more dishes and plan the feast. They might decide to feature particular dishes representative of a cultural group being studied in social studies. Food related to Mexican, Chinese, and Italian cuisines are common in American supermarkets. The feast could be prepared with foods purchased at the supermarket. If so, children would need to prepare the shopping list before the trip. If children are divided into groups, the shopping can be an adventure like a scavenger hunt and can be shared among the teams.

On-Site Activities

When the children arrive at the grocery store, they can be organized into their groups and each group's equipment supervisor can collect the clip boards, paper, pencils, rulers, hand-held calculators, and any other equipment, such as thermometers. The adults would then

Dried	*Salted/ Smoked*	*Pickled/ Brine*	*Sweetened*	*Frozen*	*Canned*	*Fermented*
soup	bacon	olives	candied fruits	vegetables	vegetables	cheese
coffee/ tea	ham	relishes	jellies	meat	fruits	beer
oatmeal	sausage	sauerkraut	jams	ice cream	meats	wine
fruits	fish	beets	sweet relishes	juice concentrate	fish	
powdered milk		carrots				

Figure 24.5 A *table showing one way to classify preserved foods at a supermarket*

conduct an orientation tour around the store. The adults can help the children in their group locate themselves on a simple floor map of the store as they walk around to the different sections. The adults can be coached beforehand and provided with suggestions for introductory questions and comments. For example, in the butchershop area,

Tell me what you see here.

Where did these items come from?

This chart (provided by the butcher) shows where he cuts the meat from the _____.

The walk-about serves as a structuring activity and it satisfies children's initial curiosity about an unfamiliar place. Children also can see where they will be working in relation to the other groups.

As depicted in the Interactive Experience Model, at the field trip site, children will be interacting with the physical environment, the objects and the spaces in the store, and will be socially interacting with their peers and the adult participants. This interaction will include recording the information they are creating in their investigations at the store.

During the on-site visit, the teacher can move between investigative groups, just to 'touch base' and encourage children's work. The teacher also will be assessing the activities and gathering examples for the post-visit discussions. Another on-site task for the teacher will be to manage the pace of the rotation and judge when to conclude the visit. If children are to make purchases, additional time must be allotted for the check out.

Following are examples of on-site activities for the grocery store field trip:

1. Different teams of children can investigate characteristics of products in different areas of the supermarket. For example, children can observe the sensory characteristics of fruit in the produce section. They might try to find the most fragrant produce item, or try to produce a classification scheme for fruits based on fragrance.

2. Children can use supermarket items to become familiar with weights and measures. Lifting a sack of potatoes can be an enjoyable way for a child to develop a personal referent for a five pound portion. This kind of basic physical-sensory experience enables children to construct more accurate internal models of the physical world.
3. Figure 24.6 shows a child using the produce department scale to weigh an item. This activity both focuses the boy's attention on the practical need for measurement in our lives, and helps him develop skills in measuring. This boy could be involved in a group investigation to find the heaviest fruit, or to compare the weights of the heaviest and lightest lemons in the bin. A more challenging problem might be to evaluate the value of purchasing the fruit pack compared to buying individual fruits.
4. The sizes and shapes of containers can be the focus of a geometry-related investigation. Children can seek out different shapes in the supermarket. They can also compare different sizes of jars, for example with peanut butter. Children could evaluate the best choice according to criteria determined by the team prior to the trip. They should have the opportunity to create their own criteria for making evaluations.
5. Children can investigate labels on products in different areas of the supermarket. For example, information is available on packages of cheese. They might also be choosing cheese to complement their tortillas for the food festival activity to take place back at school later in the week. The adult might help the children compare prices per unit and estimate the amount they will need. This kind of activity involves estimating, using multiple criteria to evaluate, and negotiating a decision in a group.

   Other grocery store areas for investigations related to the labels on items are cereals, canned vegetables, and household cleaning products. Cleaning product labels will include the product name and type, instructions for use, ingredients, safety information or cautions, storage and/or disposal information, an EPA registration number (for some products, such as disinfectants), the manufacturer's name and address, a customer information phone number, information about the material of the container (e.g., recycled plastic), and the net weight or volume of the contents in both customary and metric units. Many investigations are possible involving comparing cleaning products.
6. Investigations of the meat department may be valuable. Children can compare the qualities of the beef tissue to pork or poultry tissue. The adult might focus attention by asking, *How do the different kinds of meat appear alike (different)? What does the meat part do in a living animal?*

   Investigations in the meat department also can challenge children to visualize part to whole. This is where the butcher's chart could be a useful instructional prop. Primary children will be challenged by a question such as, *What part of the pig do you think moved when this muscle contracted?* (Some may not yet have made the connection between meat and animal muscle tissue.)
7. The children in Figure 24.7 are exploring different ways to find the number of cookies in different packages. The calculators allow the children to see mathematical relationships among counting, addition, and multiplication. As a challenge, the children could determine the price of each cookie in different packages and then record their data. Back in school the children could construct graphs comparing various brands by the cost per cookie. Activities such as these develop number sense and graphing skills.
8. Most supermarkets in the U.S. today carry a variety of items for cuisines from other lands. Mexican, Chinese, Italian, Polish, and French foods are common. Children can

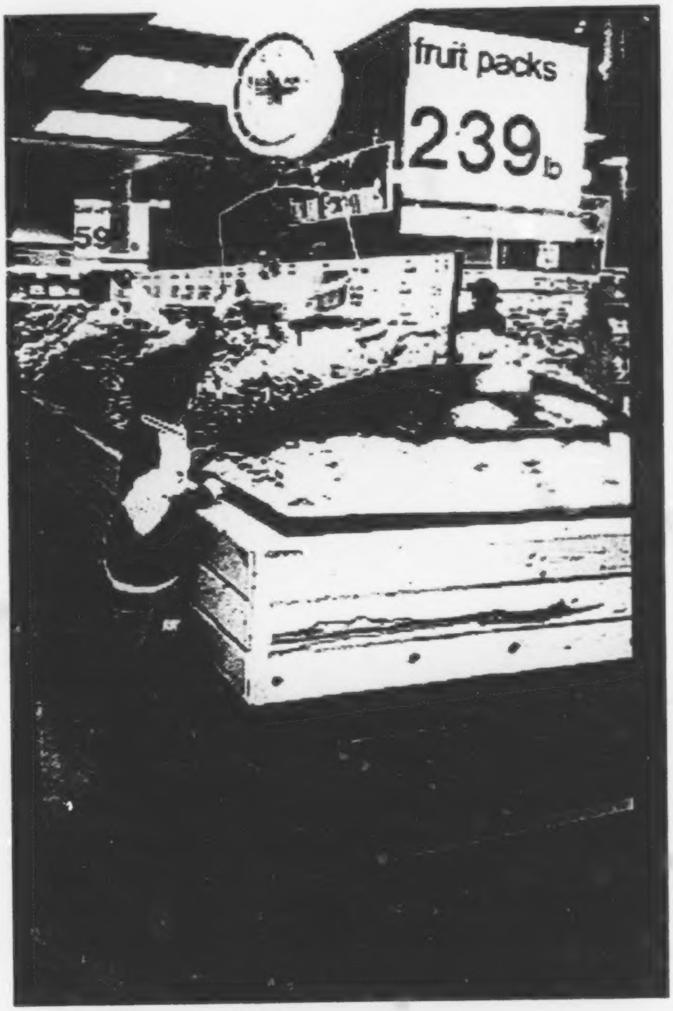

Figure 24.6 *Measurement in Produce*

observe the variety of ethnic foods offered by a supermarket. Back in the classroom, from the data recorded, the children can infer about the kinds of dishes prepared by the store's clientele.

Children can also investigate where the food was packaged. From the data recorded, back in the classroom the children can mark these locations on a world map and decide which items had been transported from the most distant site. Such an activity makes geography come alive for children.

9. The field trip concludes as children make their purchases at the check-out counter. Each team might have been issued a budget for its assigned purchases, so that children would have experience estimating and using the calculator to keep a running balance as their shopping proceeded. Back in the classroom, this experience could be connected with economic concepts like budgeting, deficit, and surplus.

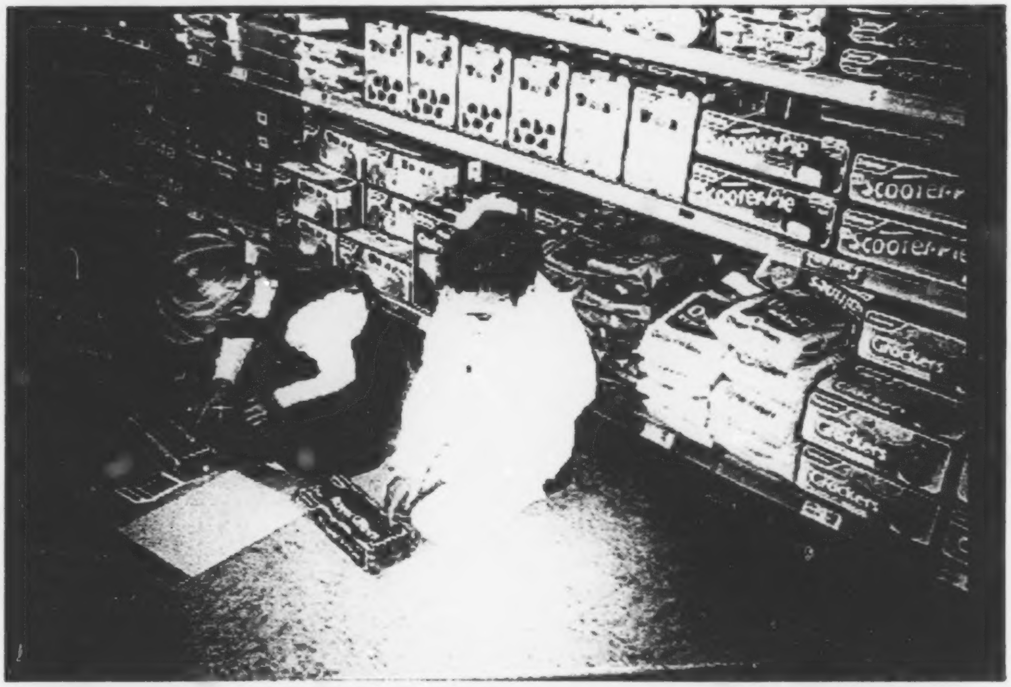

Figure 24.7 *How many cookies in a package?*

The above suggestions for on-site activities illustrate the integrative nature of children's investigations at the supermarket. These activities address content and skills in mathematics, science, social studies, and language arts.

Post-Trip Activities

One concluding activity which we recommend is the creation of one or more semantic webs that link the children's field site experiences to the concepts of the curriculum, such as estimation and measurement in mathematics, or the concepts of *fruit* and *vegetable* in science. Additional activity ideas are suggested below.

1. In the *Pre-Trip Activities* section, we discussed investigations children might conduct related to preserved foods at the grocery store. People have been preserving foods in different ways since pre-historic times. A post-trip activity would be to engage children in a study of how food spoils and how people have learned to preserve different foods. Also, primary children might want to know if consuming any of the additives they found in their investigation is safe. You can point out that scientists study such questions in their own investigations and that the effects of various pesticides and preservatives in our bodies is an area where scientists have different opinions.
2. Children can work in cooperative groups to create a mock store depicting activities in a contemporary supermarket or an old-fashioned grocery store; or they can design a wall mural or create pictures for a bulletin board. To create a large space for drawing and painting a mural, tape together two or more pieces of flipchart paper. Children can be encouraged to summarize their investigation, or think about the range of tools used in the store, the diversity of products they observed or the activities they did,

such as weighing food items and paying the cashier. Their mural might depict themselves in relation to the store or might include their own map of the store.

3. Children can use the supplies they purchased on the field trip to prepare a recipe or hold a food festival. They can work in teams to plan the feast, invite their families, and display the work they produced related to their field experience at the supermarket.

   Baking bread is an activity that connects with science concepts such as physical and chemical changes.[1] Children can make Aztec-type tortillas from materials purchased on their field trip. Tortillas, or maize pancakes, have been the central part of people's diet in Mexico and the countries of central America for centuries. Children can work in teams to read the recipe, make the dough, form it into balls, and then flatten it into pancakes. The tortillas then can be cooked and enjoyed by the whole class.

   Recipe for Tortillas

   800 ml cornmeal flour (or mix of wheat flour and cornmeal)
   handful of lard or butter
   3 teaspoons of salt
   enough water to hold it together

   Knead until rubbery and roll into balls.
   Grease the balls and let stand 20 minutes.
   Flatten the balls into round pancakes.
   Cook on hot cast iron skillet or grill until slightly brown.

   Eat with butter, syrup, jelly, or powdered sugar.

   Children can be asked, *What other foods do people eat in place of tortillas?* Bread, muffins, biscuits, buns, and bagels are all made from grains and play a similar role in people's diets as tortillas. Children can examine and compare recipes for one or more of these kinds of bread. *What ingredients are the same? What different ingredients are used in these foods?* Children can identify eggs used in some recipes, as well as ingredients like yeast, and flours made from different grains.

4. Some variety of fruit can be purchased on the field trip. To the biologist, a fruit is the seed-containing part of the plant. Examples of fruits include tomatoes, squash, gourds, melons, grapes, cherries, kiwi fruit, pea pods, mangos, and cucumbers. Children can be drawn into many possible investigations, such as a study of the shapes and symmetries found in the fruit. They might look for a relationship between the size of a fruit and the number of seeds it contains. They might investigate ways to preserve it, or study its decomposition.

5. The grocery store experience can be connected to the fine arts in the curriculum. For example, there are many songs at the primary level about different fruits - apples and bananas for example. Fruit, vegetables, meats, and fish can be found as the subjects of paintings in different periods. The Flemish masters, the Impressionists, and Modern artists like Picasso have all created interpretations.

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[1] The first wheat bread was made some 9,000 years ago from wild grasses long before grains were cultivated. This early bread was unleavened, like our pita bread today.

6. During the grocery store field trip, the teacher can obtain a number of large paper grocery bags from the store manager (they come in bundles of 500). Children in the class can decorate the bags with thank you notes, pictures of the Earth, environmental messages, the name of the school, etc. The decorated bags can be returned to the store and the store can distribute the bags (filled with groceries, of course) to shoppers.[2]

Assessing and Evaluating the Field Trip

Assessment and evaluation are processes that can be done for a variety of purposes, for example, informing instruction; communicating with students, parents, and other stake holders; identifying exemplary programs; and so forth. In this section we will limit our discussion to ways field trips can be assessed and evaluated for the purposes of improving instruction and communicating with students and their parents.

The assessment and evaluation of a field trip should be done with the same care and thoughtfulness as other aspects of the curriculum. The Assessment and Evaluation Cycle Model presented in Figure 24.8 illustrates one approach to the reflective process of assessment and evaluation of a field trip.

Beginning with the identification of outcomes, teachers need to consider the educative purposes for taking the field trip and what their students should learn within and across the

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[2] This idea comes from a project designed for Earth Day. For more information, look up the home page at: *http://www.halcyon.com/arborhts/earthday.html* .

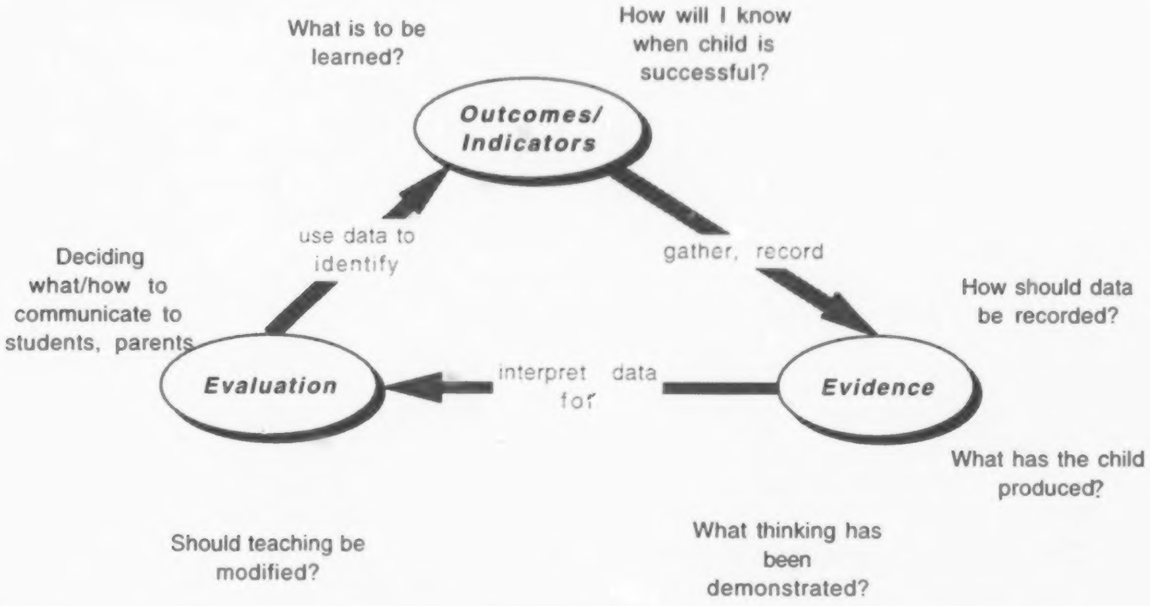
What is to be learned?
How will I know when child is successful?
Outcomes/ Indicators
use data to identify
gather, record
Deciding what/how to communicate to students, parents
How should data be recorded?
Evaluation
interpret data for
Evidence
What has the child produced?
Should teaching be modified?
What thinking has been demonstrated?

Figure 24.8 *The Assessment/Evaluation Cycle Model*

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academic areas of mathematics, science, and social studies from their field trip experience. Additionally, teachers need to engage in this process in light of the Interactive Experience Model (Falk & Dierking, 1992), therefore keeping in mind the importance of identifying both cognitive and affective outcomes. Questions like the following should be considered: What concepts and skills in the areas of mathematics are integral parts of this field trip experience? With what 'big ideas' from science do I want my students involved in connection with the grocery store? How can concepts and skills for economics, history, and geography be components of this field trip? The identification of outcomes should be accompanied by the identification of performance indicators. By noting such performance indicators, teachers are clarifying for themselves and their children benchmarks by which they can ascertain their levels of success. Examples of performance indicators in connection with a field trip to the grocery store include: developing a personal referent for a ten pound weight, identifying five citrus fruits, noting ten items in the grocery store that are produced in a different part of the world, and determining the main ingredient of a food item from examining a label.

The identification of outcomes and indicators can naturally lead to ideas related to evidence—the lower left hand part of the model. Teachers should consider and develop responses to several questions related to the idea of evidence as an indicator of student learning. For example: What constitutes evidence of a student's knowledge of the science concepts in connection with the preservation of food? What is evidence of the student's understanding of the concept of weight and the use of scales as a tool for measuring weight? Teachers also need to consider and develop responses to questions related to ways of gathering and recording such evidence. For example: At what times should these data be gathered, e.g. before the trip, during the trip, after the trip? How should the assessment data be gathered? In what ways should these data be the same as, similar to, or different from the data students gather?

After the assessment data has been gathered, it needs to be interpreted. Such interpretations need to be made in light of questions such as: In what ways do these data indicate the levels of student's thinking in connection with the performance indicators? How do these data inform the teacher as to the intended and unintended outcomes of the field trip? Which ways of gathering and recording these data worked well? Which of these data should be communicated to students and parents? How should such data be communicated? What outcomes and indicators need revision in light of these data? What additional post-field trip experiences should be provided, based on which data?

The Assessment and Evaluation Cycle Model presented here is one framework from which teachers can thoughtfully consider the effects of field trip experiences on the cognitive, affective, and social development of their students. It is through the consideration, use, and modification of such a model that all teachers can incorporate more successfully assessment and evaluation processes that mirror their instruction—with the goal of improving that instruction.

Summary

In this chapter, we considered the educational value of learning experiences outside of school. The opportunities field trips can provide children to enhance their understandings of mathematics, science, and social studies are myriad. To tap the potential richness of field trip experiences, teachers need to thoughtfully consider many questions, such as, In what ways can this experience help my children grow cognitively, affectively, and socially?, What connections among my mathematics, science, and social studies curricula can be enhanced by this field trip?, How can we organize the requisite orienting and structuring activities while building a spirit of inquiry? To aid teachers in their reflection on questions such as these, we have discussed a general model related to the planning, implementation, and evaluation of field trip experiences.

We have focused on an example of a local resource for a primary field trip, the grocery store, and discussed how this commonly found community resource can provide learning opportunities in an activity series for primary children. We showed how a field trip to the grocery store can be organized to integrate the subjects of the primary curriculum and how class experiences outside of the school enable children to recognize that their school studies are relevant to the world beyond the classroom. Primary teachers should capitalize on such community resources to help their "students understand reality by touching, smelling, tasting, pushing, shoving, banging and taking apart their world."

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Chapter 25

Integrated Mathematics and Science Materials: What are They and How do you Find Them

Kimberly S. Roempler & Marsha Paulus-Nicol

As the last of the children left for the day, Elaine sat thoughtfully at her desk. She had been preoccupied that day during her preschool classes, and she knew it. The children could sense it, too. That morning during the school staff meeting, it had been suggested that teachers try to integrate some of their math and science lesssons, and Elaine liked the idea but really didn't know where to begin. The materials they had to work with separated the disciplines, and it looked like an overwhelming task to take those same materials and somehow integrate them.

Elaine had jotted down some ideas, but she still wanted some help. Sharene, a second-grade teacher in the school, always had innovative ideas; and she was a good friend of Elaine's. Elaine grabbed her notes and made her way to Sharene's door, which was open. When she poked her head in the door, Sharene greeted her with a smile and asked, "What's up?"

Sharene had also been doing a lot of thinking about integrating math and science. She had sometimes attempted the integration, but her materials did not lend themselves to that endeavor. Was what they had been asked to do a good thing and a workable thing? Sharene shared some of her findings with Elaine.

In their visions for educational reform, both the *National Science Education Standards* (National Research Council, 1996) and the *Curriculum and Evaluation Standards for School Mathematics* (National Council of Teachers of Mathematics, 1989) had implied that integration of math and science was desirable in the school curriculum. In fact, Sharene showed Elaine page 84 of NCTM's *Curriculum and Evaluation Standards for School Mathematics* (1989) and Elaine read, "This integration of mathematics into contexts that give its symbols and processes practical meaning is an overarching goal of all the standards." But Elaine noted that she was reading in the middle-school section of the standards. What did the K-4 section show?

The ladies looked under the fourth standard—Mathematical Connections. They read on page 2, "When children enter school, they have not segregated their learning into separate school subjects or topics within an academic area. Thus, it is particularly important to build on the wholeness of their perspective of the world and expand it to include more of the world of mathematics." That made so much sense. The children that Elaine taught came to her with contextual information and a wholeness in their understanding. Was she doing them a disservice by separating their subjects? Elaine and Sharene became convinced that they were. They looked through the books that had collected on Sharene's shelf and noted that many of them taught science and used math or taught math and used science. Was that what was meant by *integrated*? They didn't think so. They decided to separate for awhile and look through materials in their rooms.

Back in her room, Elaine dug out the NCTM K-6 *Addenda Series* (1991) from her bookshelf. She opened one up and read in the Forward: "The purpose of the series is to clarify and illustrate the message of the *Curriculum and Evaluation Standards*. The underlying themes of problem solving, reasoning, communication, and connections are woven throughout the materials." There was that word *connections* again—it seemed to jump out at her. Elaine was pleased to find out that there was an investigative flavor which undergirded the activities and that connections to other areas in the curriculum were made throughout.

In one kindergarten activity, children use playground time to collect natural materials such as nuts, leaves, sticks, and pine cones. Children sort the materials into groups and talk about how the objects are alike and how they are different. The teacher models a pattern using the materials, such as: stick, stick, rock, stick, stick, rock,.... The teacher then asks children what will come next. Children work with partners and take turns creating and extending patterns. Children can then make the same pattern with other materials or they can tell what is missing in a pattern. Pattern finding and creating is an underlying concept in all of math; just as classifying and identifying objects in nature is important in the scientific endeavor. Both of these activities can be accomplished as children first identify, classify, and sort natural objects and then create and identify patterns with those objects.

In the third-grade book, there is an activity in which the class is divided into groups and each group uses a worksheet on which they make predictions about popcorn. They measure out one-half cup of popcorn kernels and estimate the number of kernels. They can discuss their solution strategies for estimating in a systematic way. Then children are asked if they think the weight of the kernels will be the same before and after popping. They can estimate the size of the container they will need to hold the popped kernels, the time it will take for the kernels to pop, and the number of kernels that won't pop. Children then pop the kernels and compare popping time and popping success rate of different brands. They can compare results of popping in an oil popper, a microwave oven, or a hot-air popper. After popping, children can graph results. Children can be challenged to find a strategy for finding the weight of a single kernel of corn. They can then talk about why popcorn pops and why the weight changes.

While Elaine was poring through her books trying to form a good concept of an integrated math and science lesson, Sharene was making a phone call to Katie, a friend of hers who taught math and science in a middle school. As Sharene had hoped, Katie had some suggestions. Katie told her about a K to 9 math and science program called *AIMS*, which was an acronym for *Activities Integrating Mathematics and Science*. She read a description of the materials from one of the AIMS books and noted that the program began in 1981 with a grant from the National Science Foundation; that they publish hands-on instructional materials that integrate disciplines such as math, science, language arts, and social studies; and they sponsor a national program of professional development. The AIMS program works on the principle that integration enriches learning and makes it meaningful and holistic. The program's rationale for integration lies in the fact the science, math, and other disciplines are used together in the real world and it follows that those disciplines should be similarly treated in the classroom.

Sharene thought she had remembered seeing the *AIMS* materials in the school library, so she decided to check there. Marie, the librarian, was helping some children, and she looked up when Sharene appeared in the doorway. Marie knew right where the materials were and she pulled some off the shelves. The first one Sharene looked through was called *Critters*, which contained activities for grades K to 6. The detailed descriptions of the activities were preceded by a lesson outline which included the topic area, math skills and science processes addressed, materials needed, a key question, background information, management ideas, procedures, and extensions.

In one lesson from the book, the key question is, "How are animal coverings different?" Math skills addressed in this activity include counting and graphing and science processes such as observing, classifying, and comparing. The children discuss animal coverings and do some activities that give them an understanding of animal coverings. In one activity, children cut out large animal drawings and glue a patch of an appropriate skin covering on each one. They can then tape a popsicle stick to the back of each picture to make an animal puppet. After children have a good grasp of various coverings of different animals, they make a picture graph by gluing pictures of animals in appropriate places under categories of *fur, feathers, scales, and smooth skin*. Discussion questions include why animals need coverings, and how different kinds of coverings meet the needs of animals. Sharene thought that Elaine could adapt some of those activities for her preschool children.

Sharene returned the book to the shelf and pulled down another AIMS book called *Bats Incredible* for grades 2 to 4. She flipped through the activities and came across one called "Spread Your Wings" in which children use drawings of microbats (insect-eating) and megabats (fruit-eating). Children estimate how many units of non-standard units of measure (like paper clips or unifix cubes) it will take to measure the wing span of each bat. They then count the units by grouping them in tens and ones. They then cut pieces of string equal to the wing span of each bat and try to find objects that measure the same length by comparing the string to them. Discussion questions are suggested, such as "How would a bat's wing span affect its ability to fly? Is bigger faster? Is smaller more agile?"

In another activity, children work in pairs to play a game in which one student plays an insect while another student plays a bat. Using a number line and guesses of "greater than," "less than," or "caught," the bat tries to guess the location of the insect. Extension suggestions include doing the same activity using a coordinate plane. Math skills used in the activity include problem solving and using logical reasoning; and math and science processes include observing, predicting, comparing, and communicating.

Sharene pulled one more AIMS book from the shelf—a K to 1 book called *Sense-Able Science* in which children explore their five senses. Mathematical concepts are embedded throughout the activities as children perform tasks such as tally and compare results; use measurement, geometry, and spatial sense; identify equalities and inequalities; and collect and record data in charts, graphs, and Venn diagrams. Life science is the foundation of the book, and specific concepts are addressed in each lesson.

The next day, Sharene and Elaine shared their findings with each other. They had seen many various examples of activities that integrated math and science and they were beginning to see ways in which math and science concepts could both be taught or reinforced in the same lesson, thereby connecting ideas, thoughts, and topics. The math and science involved included most concepts covered in the primary grades, including preschool. Elaine and Sharene were excited about what they had discovered. They decided to continue to look for materials that reflected math and science standards, that emphasized children *doing* rather then *memorizing*, that provided suggestions for teachers, and that included assessment suggestions.

Using ENC to Find Resources

One resource that Sharene and Elaine can use to find other integrated math and science materials is the Eisenhower National Clearinghouse for Mathematics and Science Education (ENC). The mission of ENC is to collect all math and science materials and to provide information about those materials to teachers three ways: through the Internet, CD-ROMs, and print publications. ENC has acquired and cataloged several thousand items, including print materials, videotapes, audiotapes, graphic images, software, kits, and Internet resources. Materials come from a variety of sources, including federal and state agencies, commercial publishers, and professional associations.

ENC Online, ENC's Internet site, provides information about real and virtual resources through its searchable online database of math and science curriculum materials and also provides links to exemplary math and science Internet sites, and entire documents in electronic format regarding curriculum issues in math and science education. *ENC Online* is available via the Internet (URL: http://www.enc.org) through modem access with a toll-free number ((800) 362-4448, or locally: (614) 292-9040), and on CD-ROM. For help with any of these services, call (800) 621-5785 or (614) 292-9590, or send an e-mail message to *help@enc.org*.

The searchable fields of *ENC Online's* database, *Resource Finder*, include grade level, cost, words, subjects, authors, title, series, ENC number, standards, resource type, audience, and language. Catalog entries contain a detailed abstract, availability information, the entire table of contents, specifications, equipment requirements, field test sites, and evaluations. For example, the standards field includes information about whether an item follows Project 2061, the National Council of Teachers of Mathematics, or the National Science Education Standards.

One of the important features of the ENC catalog is the ease with which users can search for items of interest. Searching is easy because all the necessary information is available on the screen when users log in. It is also possible for users to identify precisely the materials that will meet their needs, because searches may be limited in several ways, such as grade level and media type. Elaine and Sharene can do a subject search using the following words: *Integrated*, *Mathematics*, and *Science*. Grade level can be used as a limiter. They can then limit even further by using specific topics or resource type such as print materials, software, or CD-ROMS.

Teachers report they are using *ENC Online* in a variety of ways. Primarily, they are retrieving information from the ENC *Resource Finder* on math and science curriculum materials that they can use in their classrooms. They can also easily explore math and science Internet sites from which they are able to retrieve information to use in writing proposals for additional funding, planning lessons, or developing student projects, including projects using the Internet.

Using ERIC to Find Resources

Another resource available to Sharene and Elaine is the Educational Resources Information Center (ERIC). The ERIC system has developed the world's largest education-related, bibliographic database over the past 30 years and now has over 900,000 records. The records include references to articles in over 750 journals, as well as books, reports, curriculum guides, and many other types of documents. The ERIC database can be accessed in a variety of ways in most libraries, but the most popular ways are by searching on CD-ROM or through the Internet. ERIC has over 20 searchable fields, but the most useful field for quickly finding what you need is the ERIC Descriptor field. ERIC Descriptors are indexing terms that are used to identify the primary subject matter and grade level of materials. You can access the ERIC system on the World Wide Web at *http://ericir.syr.edu* or *http://www.aspensys.com/eric/* where you can search the database or browse the many other resources available from the virtual library.

If you are unfamiliar with ERIC or searching the ERIC database, you are encouraged to use electronic mail to seek assistance. Just send your question via e-mail to askeric@ericir.syr.edu and someone in the system will get back to you within 48 hours.

Description of Integrated Math and Science Materials

Literature-Based Materials

The Scholastic *Banners* curriculum focuses on personal, social, and natural world themes that are appropriate to grades K to 2. Children are encouraged to explore each theme through literature (classic and contemporary), music, poems, fingerplay, and integrated science, math, creative arts, social studies, geography, and language arts activities. The themes in the *Banners* program are arranged into three groupings: Yellow Themes include gardens, food, animals, myself, seasons, and senses; Red Themes include water, homes, families, bugs, holidays, and weather; and Blue Themes include space, environments, dinosaurs, communities, work, and transportation.

Dinosaurs, one of the Blue theme kits, encourages children to explore science topics through integrated literature, science, math, social studies, and creative arts activities. For instance, children are asked to write a newspaper article, make a giant picture graph, find similarities, plot on a map, and construct skeletons all in the context of learning about dinosaurs. The books that come with this kit include *Giant Dinosaurs* (contains humorous drawings and compares the size of seven dinosaurs from fierce Tyrannosaurus to gentle Brachiosaurus); *Hunting the Dinosaurs* (a reference book that explains how scientists unraveled the mysteries of dinosaurs from the fossil record, and provides facts about dinosaurs and the world they inhabited); *Tyrannosaurus Was a Beast* (contains funny poems about 17 different dinosaurs); *Dinosaur Time* (tells about eleven different dinosaurs, and illustrates the time when dinosaurs ruled the earth); *Dinosaur Bob and His Adventures* (talks about a dinosaur brought from Africa by the Lazardo family which turned out to be a great hero); *Tyrone the Horrible* (illustrates a little dinosaur who found a strategy to stop a dinosaur from bullying); and *Dinosaur Garden* (illustrates the story of Rex and Bones who found a dinosaur egg and planted a dinosaur garden).

Each kit includes a teacher theme folder, teacher plans for each book in the kit, a program guide, two big books, a big book easel, small books, a theme banner, cassette tapes of books and songs, a theme bag, and song charts. The teacher theme folder provides a list of learning concepts, theme starter activities, ongoing theme projects, an outline of the theme books and activities, and a culminating theme event. Teaching plans, one plan for each book in the kit, include teaching tips, modeling strategies, process oriented activities, assessment ideas, and activities to be done at home. The program guide describes the entire *Banners* program, provides instructional plans for using the materials, guidelines for evaluation and assessment, a student evaluation sheet, and a list of resources.

The *Themeworks* teacher resource books, published by Creative Publications and developed for grades preK to 2, present an integrated approach to teaching the curriculum. Each of these books centers on one powerful theme and as children investigate the theme they engage in language, mathematics, science, cooking, poetry, literature, dramatization, and art activities. The theme also provides a springboard for large scale projects, dramatic play centers, and the construction of classroom environments. The whole language approach to developing language skills is heavily favored in this series and exposes children to language through chants, songs, stories, poems, and rhymes. Counting and number work are developed through meaningful problems that evolve from real situations relevant to the theme. Each theme is organized into three distinct parts: the kickoff, the theme activities, and the culminating event. The theme activities are divided into 18 mini topics related to the theme at large, each of which contains several activities. For example, *Under the Ground* contains activities in which children learn about animals that live underground like moles, worms, and ground hogs; meet people who work underground, such as miners, sewer inspectors, and subway clerks; and learn about plants, including their soil, roots, and seeds. *Rain* contains activities in which children learn about weather such as floods, hail, lightning, thunder, rainbows, and clouds; forecasting the weather; the desert and rain forest and the plants and animals that are found in each ecosystem;

and the evaporation of water. A curriculum chart which identifies each activity by discipline and a resource list of fiction and nonfiction stories, number books, poetry, and songs are also provided. Other titles in this series include *At the Seashore, Houses, Night Time,* and *Trees.*

Integrating Mathematics, Science, and Language, published by the Southwest Educational Development Laboratory and developed for kindergarten to grade 3, is a two volume curriculum and resource guide designed to help elementary school teachers organize their classrooms and instructional activities in order to increase achievement of Hispanic primary grade children whose first language is not English. The guides offer a curriculum plan, instructional strategies and activities, teacher and student materials, and assessment procedures. Motivational strategies and materials compatible with the children' own social and cultural environments are incorporated into the instructional materials to develop and enhance positive attitudes and values toward mathematics, science, and language learning. Volume 1, developed for kindergarten and grade 1, covers the following units: the senses, spiders, dinosaurs, plants and seeds, the human body, and good health. Preceding each unit is a Spanish version of background information as well as a Spanish version of the formal introductory portion of the lesson cycle.

Presented first in the unit overview is a recommended list of content or skills children should have as prior knowledge before doing the unit activities. Specific mathematics, science, and language objectives are listed followed by a topic concept web that shows relationship among the various science content elements presented in the unit. The web prompts the identification of two major ideas, one in science and one in mathematics, that the class will develop in each lesson. A list of key vocabulary items in both English and Spanish, teacher background information, and the lesson focus that lists each of the big ideas presented in the lessons are provided. Each big idea is stated as an overarching concept in science or mathematics that generates the lesson activities. Following the lesson focus is an objectives grid displaying the unit objectives by content area and by lesson activity. Each lesson provides the instructional context and the activities for the children to acquire the concepts or build the constructs contained in the lesson's big ideas. The lesson's content develops through a process which includes encountering, exploring, getting, organizing, and applying the idea. Oral and performance assessment strategies are provided at the end of each lesson.

Science Place, a collaboration between Scholastic and the nation's leading science museums, is a hands-on, thematic, core K to 6 program offering six complete kits for each grade. Each kit offers active, hands-on experiences to help children learn how to analyze and utilize information constructively and develop an understanding of life, earth, and physical science concepts that explain the world. Each kit includes books, a teacher's map to exploration, reusable exploration materials (equipment needed for each exploration), sciencemats, an assessment collection, recording board, home connection collection, audiocassettes (spoken and musical version of the books), description of the Science Place Program, and a bag.

A kit designed for kindergarten, *Alive: What Living Things Are,* covers the topics of living things, their differences and similarities, and their life cycles. The books in this kit include *In The Woods* (a book of illustrations presenting a close up view of some of the animals and vegetation found in the forest); and *Have You Seen Birds?* (provides pictures of birds in various natural environments). A teacher's map to exploration provides lesson plans for each book, includes thorough background information and options for exploration, and provides teaching and assessment ideas. Sciencemats provide reproducible sheets with pictorial directions for each exploration and a journal format for children to record their observations and conclusions. The assessment collection provides lesson assessments, baseline and follow up assessments, step by step guidelines for using portfolio and performance assessments, rubrics, and observation checklists. The home connection collection consists of letters (provided in multiple languages) to go home at the start of each unit to give families a snapshot of the unit explorations and concepts as well as family activities. The other kindergarten kits include *Your Senses, Day and Night, Your Earth, Matter,* and *What We Use.*

The *Reading Rainbow* series, distributed by Great Plains National (GPN), also includes literature-based integrated math and science materials. Each *Reading Rainbow* program is based on a highly acclaimed children's book and is designed to encourage and motivate young children to read good books and visit their local libraries. *Reading Rainbow* enables teachers to integrate their math, science, social studies, and art curricula through the medium of television. The format of many of the programs invites viewers to see that math and science are everywhere in our world. Math and science guides have been designed as a supplement to many of the programs. The guides include math and science concepts, classroom activities, and a do-at-home activity. The math and science concepts that are identified for each program are embedded in the programs themselves and in the feature books. Titles include *Digging Up Dinosaurs, Is This a House for Hermit Crab?,* and *Gregory the Terrible Eater.*

Many children's literature books also integrate math and science ideas. For example, *Ten Little Mice,* published by Harcourt Brace & Company, provides a lesson in subtraction for young children. Ten little mice snoop and sniff and spy and climb through the fields near their home meeting the animals and insects that live in the area. One by one, the mice tire of their adventures and scurry back to their nest. In this book, children also learn what mice eat, where they live, and about other animals and insects that live in the field. This book includes intricately detailed colorful illustrations.

Other Resources

The Science Book of Numbers, also by Harcourt Brace & Company, integrates math and science through investigations. By following the steps of each activity, children can learn about counting systems and number relationships. Activities include making an abacus and a slide rule; making a counter that works in the same way as a car's odometer; making snowflakes and finding their lines of symmetry; creating a sundial from a flowerpot, a pencil, and a piece of cardboard; and making a staircase and using colored candies to move up and down the staircase to find out how numbers show both size and direction. Each activity relates the principles involved to real world situations. For example, the staircase activity is related to thermometers which use zero and negative numbers. It is noted that water freezes at zero degrees Celsius and any temperature below that is shown as a negative number.

The *Great Explorations in Math and Science* (GEMS) series of resource books contain guided discovery, hands-on activities that include step by step instructions and background information to allow presentation by teachers without special background in math or science. *Frog Math,* developed for grades K to 3, integrates science, literature, art, and writing with math. The activities included in this guide are intended to develop in children such skills as observation, prediction, classification, estimation, and recording data. Children begin by listening to a story from Arnold Lobel's *Frog And Toad Are Friends* about a lost button. Children then explore attributes of buttons as they sort and classify real buttons and create paper buttons and organize them on a grid. In other activities, children estimate the number of plastic frogs in a jar, and play games designed to develop logical thinking skills and introduce probability and statistics.

The GEMS guide, *Tree Houses,* designed for preschool to grade 1, encourages appreciation for trees and animals that live in tree homes. Life science, math, and physical science concepts are presented in hands-on activities stimulating children's interest in the world around them. A life science concept in this guide is the dependence of many animals on tree holes for warm, safe homes. The children become familiar with a living tree, then build a child-size tree from cardboard boxes, paper, and cardboard tubes. The group participates in class plays about a mother bear and her cubs, raccoons, and a family of owls and their tree homes. The math concept of measurement is emphasized as the children compare sizes of boxes and sizes of toy animals, and logical thinking skills are emphasized as children classify the toy bears and other animals brought from home. Extension and age modification suggestions are included throughout the entire GEMS series. Also included are source lists for suggested materials, bibliographic information for suggested books, and blackline masters. A teacher's guide, a leader's guide, a parent's guide, and Spanish translations of the blackline masters are available for the series.

A resource for the elementary classroom, *Marine Mathematics for the Elementary Classroom* published by Sea World, is designed to apply basic math operations and graphing to marine situations. Children learn about marine animals, waves, pollution, and more, and at the same time learn math concepts in applied situations. Activities in this guide are designed to be used in a thematic unit incorporating math and science or in conjunction with a visit to Sea World. It is intended that children will be able to apply basic mathematical operations to marine situations, solve marine problems involving metric and customary units that require multistep computations, use the calculator as a problem solving tool in marine science applications, and construct and interpret graphs from marine data. In one activity, children try to determine how long fish (used in diets of many animals at Sea World) will stay frozen. Children create their own method of insulation; place an ice cube in their insulation material; leave it for a given time; and use information about the activity to generate data, pictures, and graphs, and to discuss results. In another activity, month by month data are given to show how much marine mammals weigh during the first year. Children are asked to indicate which months show the most growth for each animal. A glossary, an answer key, a bibliography, and background information are included in the book.

The *Best of BAESI* is a collection of activities modeled by participants in the summer workshops of the Bay Area Earth Science Institute (BAESI), that provide grade K to 12 teachers with Earth science concepts, strategies, and resources for teaching them. In addition to creating wholly original activities, BAESI teachers adapted materials from a wide range of sources to produce activities that reflect their own teaching philosophies and styles. The first section contains 19 hands-on lessons that cover the topics of topographic modeling, classification, the dynamic nature of Earth, physical properties of minerals, the rock cycle, rock identification, energy usage, earthquakes, sea floor spreading, volcanoes, and radioactivity. Activities include recommendations, where appropriate, for making connections via *California Science Framework* themes and suggested tie-ins with chemistry, physics, life science, geography, mathematics, and social studies. They also include background information, suggested activity set up, framework integration (themes, science skills, integration with other disciplines such as math and social studies), modifications and extensions, teaching resources, and student activity sheets. The second part describes additional books, slides, and videos which relate to the activities as well as to many other aspects of geology, astronomy, meteorology, and oceanography. It also identifies government agencies, professional societies, teacher organizations, and periodicals related to earth science education.

A professional guide, distributed by Dale Seymour, Inc., that outlines a program developed to give primary school children challenging and meaningful experiences in math is entitled *How Big is the Moon?* This program uses a "whole maths" approach that reverses the traditional model and moves from meaningful applications of mathematics to basic number facts and operations. The book attempts to integrate mathematics into the broader curriculum through the exploration of facts, skills and concepts in purposeful and meaningful contexts. Suggested activities include investigating water (floating and sinking), exploring bubbles, and building a model of a zoo.

Environmental Education Activity Guide: Pre K to 8 is organized using *Project Learning Tree's* (PLT) five major themes: Diversity, Interrelationships, Systems, Structure and Scale, and Patterns of Change. A variety of hands-on activities are used to integrate these themes into science, language arts, social studies, mathematics, art, music, and physical education. The guide is designed so that teachers may vary the program activities to fit the context of their individual classrooms, interests, or community. The activities can be used individually to teach specific concepts or they can be used with other activities as part of a conceptual storyline. The activities are based largely on the constructivist learning theory, which recognizes that children construct new understandings by combining previous understandings with new discoveries; and the whole language teaching strategies, where children are taught holistically rather than in bits and pieces.

PLT focuses on connecting themes, conceptual understandings, and critical thinking skills rather than on the transfer of bits of information. The storyline technique is used to group several activities around a central core of knowledge and skills. Each activity outlines an overview of the activity, grade level, subjects covered, the activity concept, skills, objective, materials, and time considerations. A diversity activity, Part A designed for PreK to K and Part B for K to 3, has children playing a game of I Spy. Children make necklaces of different shapes and wear them when they go for a walk. When they see an object shaped like their circle, square, oval, or triangle necklace, they say, I spy something shaped like a triangle. Another activity designed for grades K to 6, has children observing tree buds throughout the year to learn where the leaves come from and how they are formed. Other activities investigate species diversity, diversity of habitats, predator and prey relationships, and the five senses.

One Year Later

Sharene and Elaine had found some materials that integrated math and science and had used them throughout the year. They got together at the end of the school year to talk about the past year and to plan for the following year. The past year had gone well for them. They had found many ways to integrate math and science, and the children had seemed to enjoy the "connected" activities. They had learned science (animals, plants, and the weather), while also learning about math topics, such as graphing, computation, and place value.

The teachers had combined weather, health, graphs, place-value concepts, patterns, and general number sense in daily activity involving the calendar. By graphing sunny, cloudy, and rainy/snowy days, children learned about weather and bar graphs. By counting the number of days since the beginning of school and bundling every group of ten ones and every group of ten tens, children learned about place value in context. Patterns were generated and even/odd concpets were learned by putting pictures on the even days and different pictures on the odd days. Children talked about the lunch menu for the day and tallied or graphed the number of children who liked the different items on the menu. Nutrition and the food pyramid were discussed. These activities and others involving the calendar provided daily integrated activities to reinforce concepts in context. The children liked the activities and learned much about the world, their health, and the math and science that helped make it meaningful.

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Publisher Phone Numbers for Materials

AIMS Education Foundation; (209) 255-4094
The Bay Area Earth Science Institute (BAESI); (408) 924-5030
Creative Publications; (800) 624-0822
Dale Seymour Publications; (800) 872-1100
GEMS; (510) 642-7771
Great Plains National (GPN); (800) 228-4630
Harcourt Brace & Company; (800) 543-1918
National Council of Teachers of Mathematics; (800) 235-7566
Project Learning Tree (PLT); (202) 463-2462
Scholastic, Inc.; (800) 325-6149
Sea World of Florida Education Department; (407) 351-3600 Ext. 3391
Southwest Educational Development Laboratory; (800) 201-7435

Chapter 26

Integrating Methods

Peter Rillero

In this book we describe and present examples of activity series, activity centers, and projects. We proffer methods for integrating mathematics and science with each other and with other content areas. We hope we stimulate your thinking and expand the skills, techniques, and strategies you feel ready to employ in the early-childhood classroom. Of course, it is easy to grab onto familiar ideas and ignore those outside our direct experience, yet growth occurs when we expand our abilities. Stretch beyond your initial level of comfort and try a variety of the methods described in this book. In this chapter, I explain that an integration of diverse methodologies makes learning more meaningful to a greater number of children. I present examples of integration of method found in this book.

Integration of Method

Benefits of Multi-modal Approaches

Children are different—different from adults and different from each other. It would be ineffective to teach the majority of young children as though they were adults—with only lectures and textbook readings. One of the joys of spending time with children is learning how they differ from each other. They have different gifts, different personalities, different levels of development, different ways to understand the world. One teaching method may provide strong benefits to some children, while another way provides great learning opportunities for others. Using diverse methodologies is an effective way to ensure that learning is for everybody.

Diverse methodologies keep things interesting and children interested. Experiencing the world through different contexts helps keep learning fresh. When comfortable, children's eyes widen at novel stimuli—a guest speaker, new instructional software, a new activity center. Multi-modal learning environments keep children interested and focused on learning.

Diverse methodologies help maximize use of resources. Classroom resources include teachers and other helpers, materials, and time. A teacher may feel she can help the most children, when they are all doing the same activity. She can give class instructions and then walk around and give group and individual assistance. Another teacher may feel class time is optimized when all students water their plants and measure their growth at the same time. In a different classroom, another teacher has decided to create a weighing activity center because they have only one scale, but he wants all the children to be able to use it. Resources are an important consideration for methodology usage; flexibility in method is often the best approach for maximizing resources.

Using diverse methodologies in the early childhood classroom ensures that all children have opportunities for growth and learning. Resources are used efficiently. Learning is fresh and alive. In the next section, I describe how activity series, centers, and projects can be used together.

Integration of Activity Series, Activity Centers, and Projects

Effective activity series, activity centers, and projects stress activity rather than passivity, understanding rather than memorizing. All three provide direct experiences to help children understand their world. These experiences are linked in meaningful ways. Through time for reflection, social interactions, and teacher questioning, they help children build deeper understandings of their world.

Activity series, activity centers, and projects have differences. Generally, activity series involve all the children in a classroom—working in small groups or individually—doing the same sequences of activities over a period of time. Activity centers also feature linked activities, but these are located in a special area of the room. Children can do the center activities at different times during a day or week, for different amounts of time, and they can revisit the center a number of times. While activity series and activity centers are chosen to match children's interests and abilities, it is common for teachers to use some similar series and centers from year to year. Projects are different, they sprout from the immediate expressed interest of the children, and thus, teachers and children will often embark on very different projects each year. They are similar to activity series in that the whole class usually moves through the project over time. Projects are similar to activity centers in that it is common for students to break into groups and explore very different aspects of the project.

There is a place for all three approaches in the early childhood classroom. These types of learning experiences—because they are different—can be synergistic. Children enjoy and prosper in all three types of learning environments. How spectacular to see children during "centers' time" or "free-play time" running to the mathematics or science centers. How wonderful to observe all the children—having worked on a science activity series during the week—energetically discussing a bulletin board graph of their results. How exciting to witness children near the completion of a project, decide they want the project to continue but in a different direction.

The authors of this book present many examples of projects, activity series, and activity centers being effectively used together. For example in Chapter 24, Bentley, Bloom, and Reynolds describe a field trip to a grocery store as a setting for activity centers. They suggest pre-trip and post-trip activity series and projects to enhance the learning experience. In Chapter 21 students learn about food groups from learning centers, followed by a class activity where students paste appropriate pictures onto paper plates representing breakfast, lunch, and dinner. The children use tally marks to keep track of the number of times they use each food group. In Section Four on The Project Approach, all of the chapters use projects with activities and centers. The complex and generative nature of projects provide many opportunities for different learning methods. Activity series, activity centers, and projects can and should be used together to enhance learning experiences.

Integration of Other Methods

Learning can flourish in many environments. While the main focus of this book has been on activity series, activity centers, and projects we have presented many other methods to enhance teaching and learning. One of the most important methods for improving learning in activity-based instruction is creating opportunities for children to discuss what they observed, investigated, or learned. For children to talk they must think about their ideas, organize them, and then share them. This process is a powerful catalyst for learning. In discussions, students compare their ideas with others and negotiate shared meaning. Discussion boosts the effectiveness of other methods.

Learning cycles are a powerful method to enhance learning and understanding. Roychoudhury and Johnson use a learning cycle in Chapter 5 with the phases of exploration, concept introduction, and expansion to structure an activity series for simple machines. In Chapter 20, Westbrook describes the *Shadows* and *Seeds and Fractions*, two activity series that use the learning cycle to teach concepts in mathematics and science. FoulksBoyd, Dickman, and Van Sickle use a 5 Es approach with the following five phases: engagement, exploration, explication, elaboration, and evaluation. This approach in Chapter 6 structures an activity series to help children learn about weather.

Some activities explain what children should do, others are more open-ended and allow students to determine their own methods and even their own problems to investigate. In Chapter 5, the question, "Why are the ramps for physically challenged persons so long?" guides an open-ended investigation. In Chapter 14, children are challenged to find the fastest way to melt an ice cube. Chapter 10 uses an open-ended task called "Pet Paradise." Children design and construct a home, transport device, or entertainment facility for pets. Notice in the Project chapters of Section Four how teachers let children guide the direction and nature of the investigations.

Music can also help children learn. In Chapter 6, the "Water Cycle" song captures children's attention in the Engagement phase of an activity series. In Chapter 10, children learn about pitch, loudness, and sound quality by exploring aspects of different musical instruments. They then used the instruments to play songs. To help children master ideas about patterns in Chapter 20, Westbrook uses music, specifically rhythm, verse or chorus, and repeating measures.

Children's constructions of their own representations through art experiences helps them construct their own understanding. When children create and color their own constellations in Chapter 8, they learn that ancients used their imaginations to develop constellation names we use today. In Chapter 6, children draw the water cycle to help learn important concepts. Children draw animals to focus on their characteristics in Chapter 10. They learn to do enlargements and reductions as a way to learn ratio and proportions. In Chapter 9, Foster uses seed art to teach geometry.

Children's literature can be a powerful learning tool in the early childhood classroom. It can also be a very effective method to teach science and mathematics. Downing and Benson present an excellent rationale for using literature in Chapter 22. They also present many examples of how to use specific literature to teach science and mathematics.

Literature enhances learning in many places in this book. For example, in Chapter 7 before children make a model of the Earth they read *The Magic School Bus Inside the Earth* by Joanna Cole. In Chapter 8 children learn about other cultures and their views of the night sky through diverse children's literature. In Chapter 23, Roempler and Paulus-Nicol describe many published materials that use literature to teach science and mathematics. They also discuss how to find more materials using the databases of the Eisenhower National Clearinghouse and the ERIC system. Stevenson and Broyer present innovative ideas in Chapter 22 in their explanations of how teachers can create kits for parent-child experiences in literature and mathematics.

As you review the chapters in this book, many powerful methods will be revealed. These methods used in conjunction with other methods can add a great deal to the learning environment. A multi-modal environment provides fresh opportunities for growth; it ensures that all children have the opportunity for learning.

Conclusion

In the introduction to this book I used a metaphor of children learning about a forest to describe activity series, activity centers, and projects. This metaphor was useful because it gives a good visualization about how these approaches are similar and different. In activity series, the children and teacher walk in on a path, along the way they make a stop, experience the forest individually or in small groups, come back together and continue down the path for more shared experiences. In an activity center approach, the class walks into the forest and children disperse into groups and experience different aspects of the forest. In time they come back, while they may have experienced different things, they all have experienced the forest. In projects, there is no path, but the teacher and children decide where they are going to go, and what they wish to learn. They walk into the forest and experience it.

It is important to realize that it *is* the learning, *not* the method, that is most important. In all of the aforementioned forest scenarios, children are learning about the forest. This book presents many ways to help children understand their forests, their worlds. The events you help create with children, whether activity series, activity centers, projects, or other methodologies become "elements with in a theme," or tiles in the mosaic of your children's lives. As an early childhood educator you can help create a variety of beautiful influential events. We wish you and your children a wonderful trek in the shared journey of event-full learning.

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